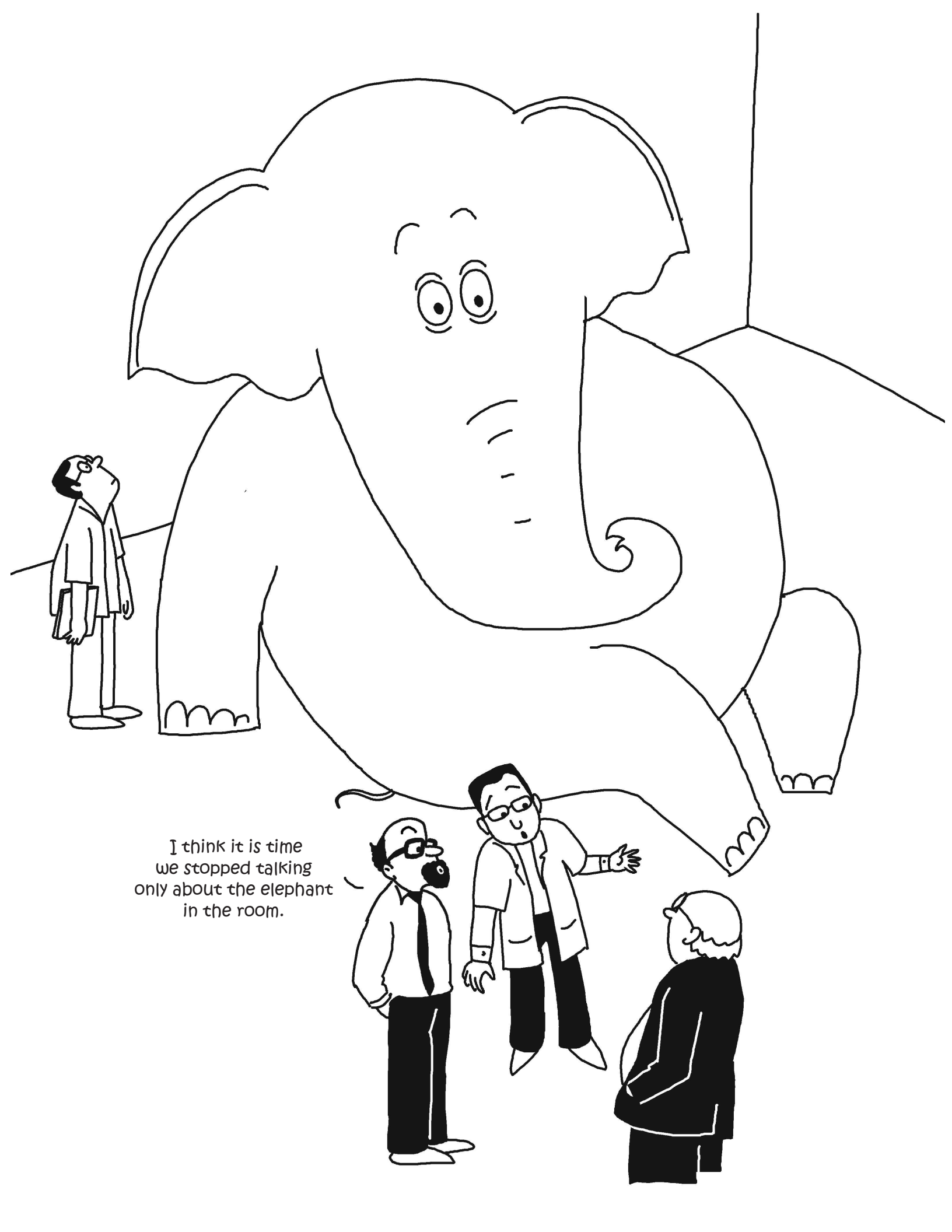
The Amoeba in the Room

Charudatta Navare

Illustrated by Reshma Barve

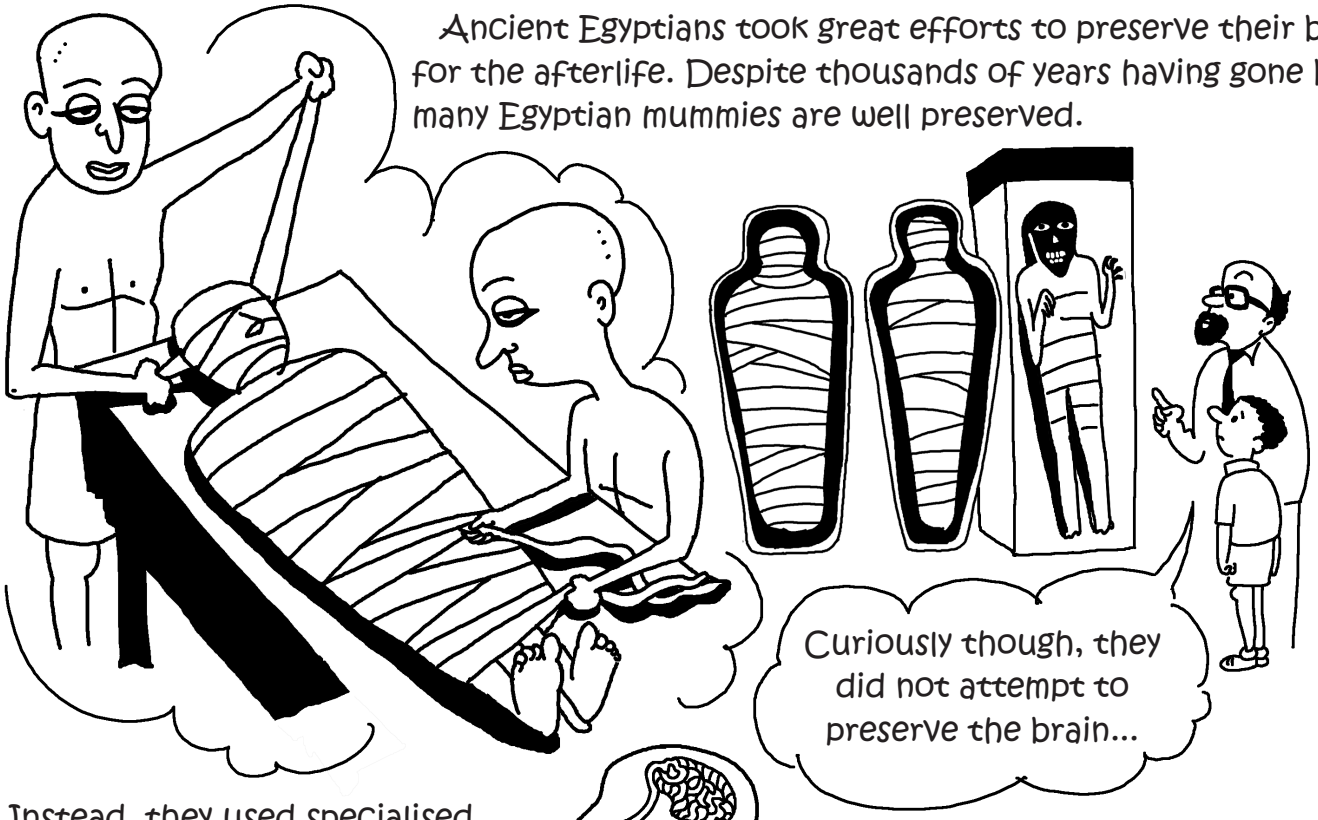

I think it is time we stopped talking only about the elephant in the room.

The Amoeba in the Room

The Amoeba In The Room

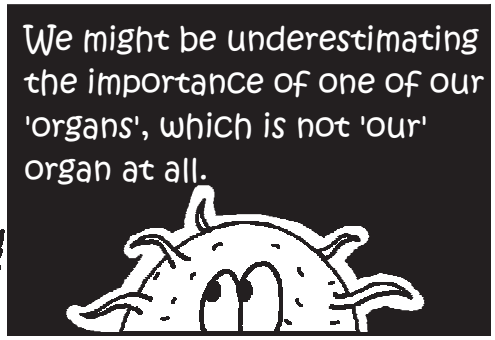
Mummies, Guts and Brains

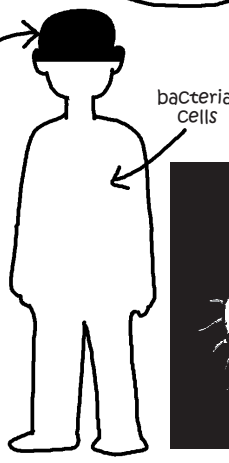
Ancient Egyptians took great efforts to preserve their body for the afterlife. Despite thousands of years having gone by, many Egyptian mummies are well preserved.



...Instead, they used specialised tools to remove the brain through the nose.

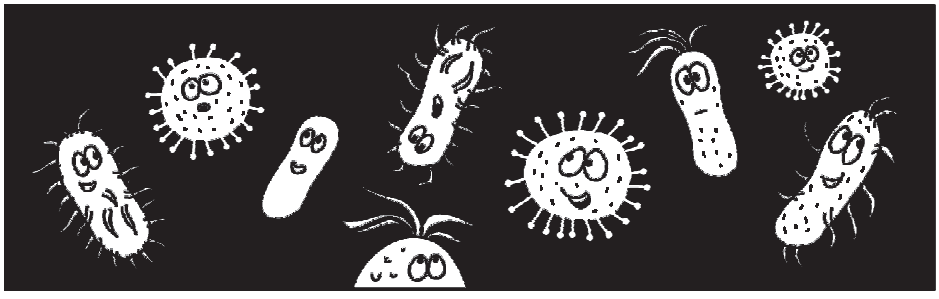
The ancient Egyptians did not think brain would serve any purpose in the afterlife.



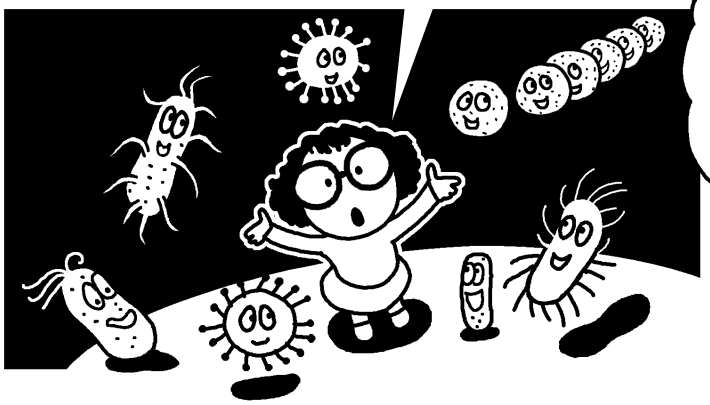


Let me explain what I am talking about. Our body has about ten times as many bacterial cells as human cells.

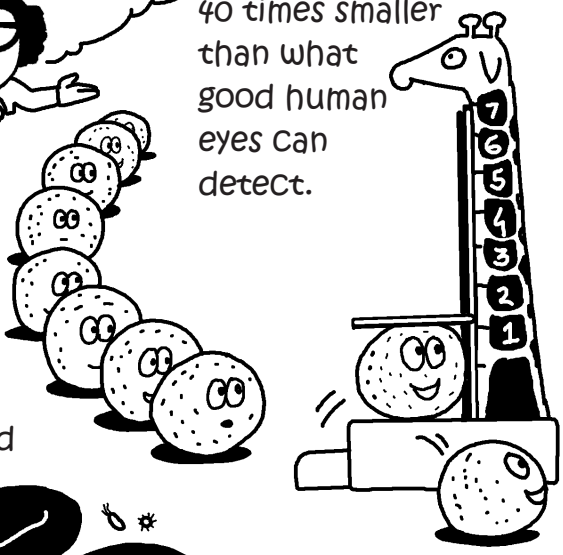
Many microbes live in or on our body:



including our skin, eyes, nose, lungs, stomach, intestine. They are in our food, air, soil ...

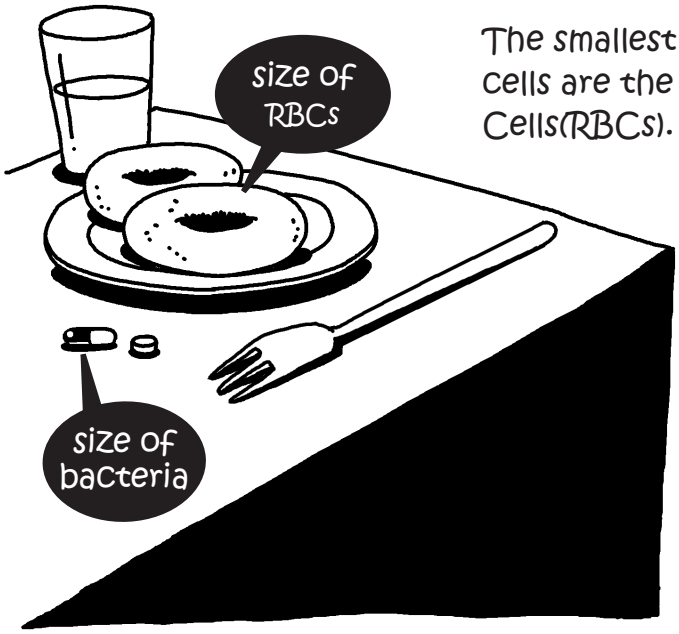


A typical bacteria cell is about 1 micrometer in length that's (1/1000,000) meters.



40 times smaller than what good human eyes can detect.

Our skin cells are about 30 times bigger than a bacterial cell.



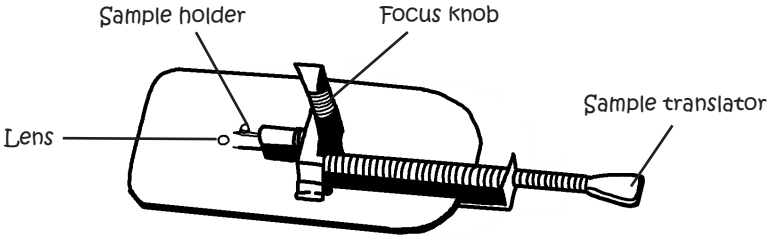
The smallest human cells are the Red Blood Cells(RBCs).

RBCs have to be able to slide through the thinnest of the blood capillaries to supply oxygen to the body cells everywhere.

RBCs are about 8 times bigger than a typical bacterial cell, while the largest human cells, the egg cells, are 120 times bigger.

Antonie van Leeuwenhoek

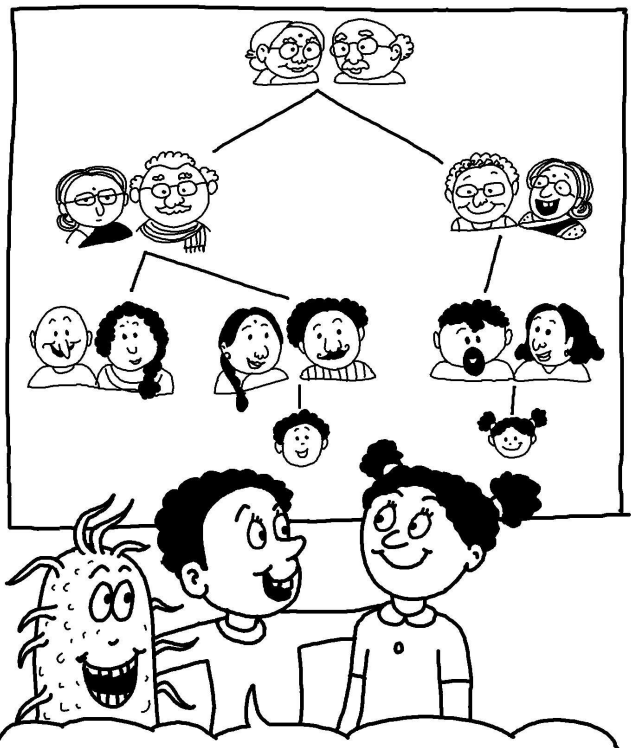
This is why the earliest detection of bacteria had to wait for the invention of light microscope.



Leeuwenhoek microscope

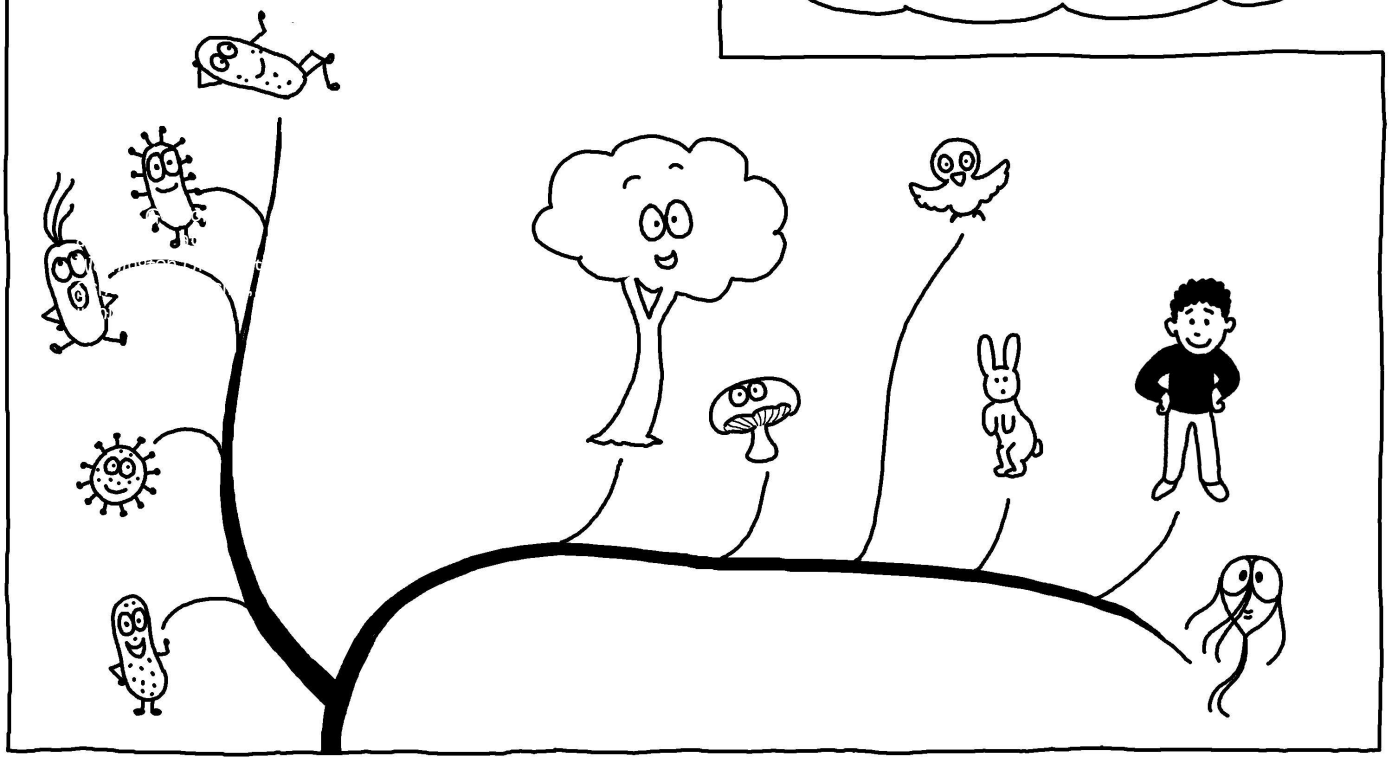
Antonie van Leeuwenhoek observed bacteria in 1676, using a microscope of his own making.

When you think about it, bacteria are our cousins.

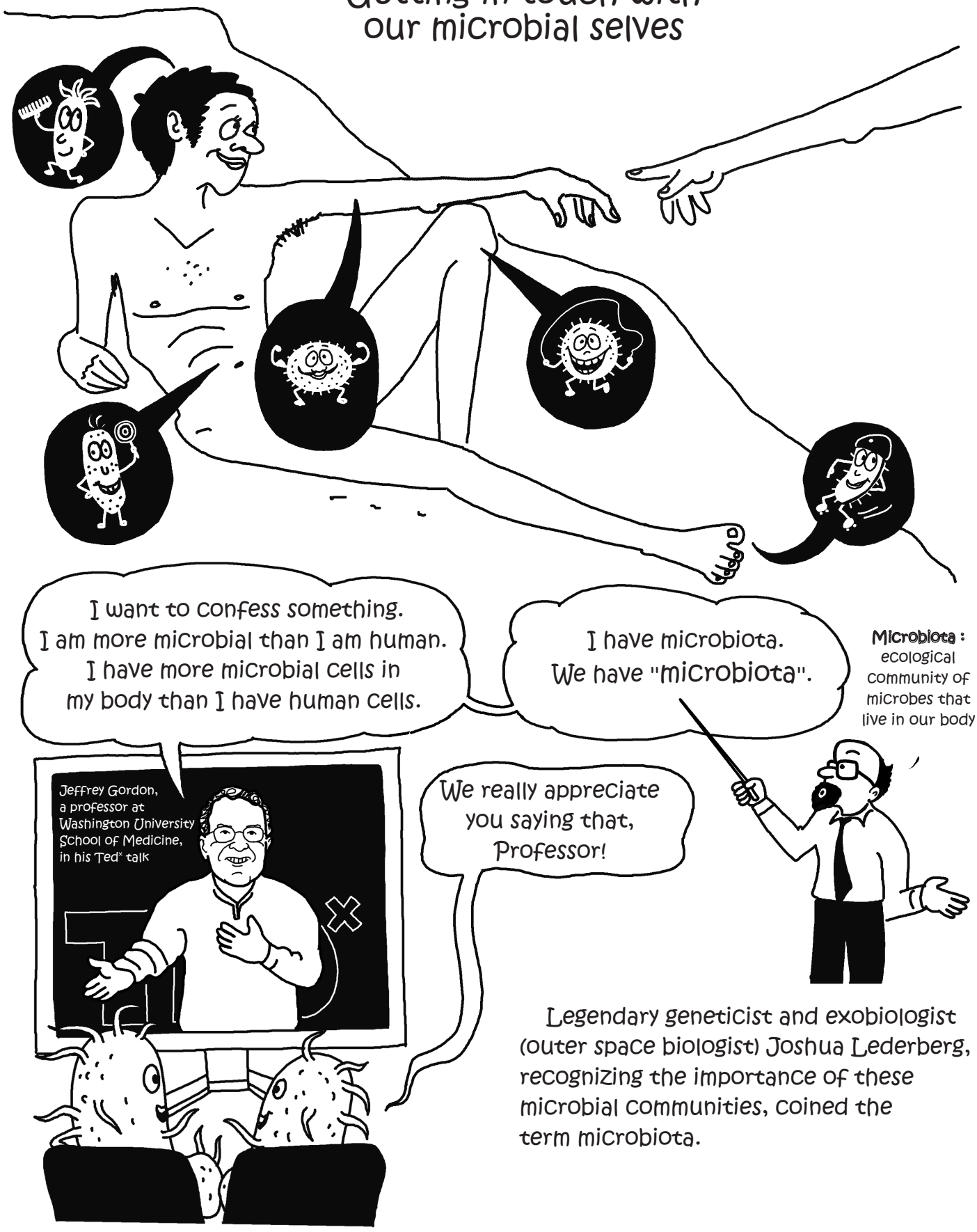


This is my second cousin. Our common ancestors, my great--grandparents, was born 125 years ago.

The common ancestor of bacteria and us lived about 3.8 billion years ago. That's 3,800,000,000 years. Long time, I know. But we are still a family.



Getting in touch with our microbial selves

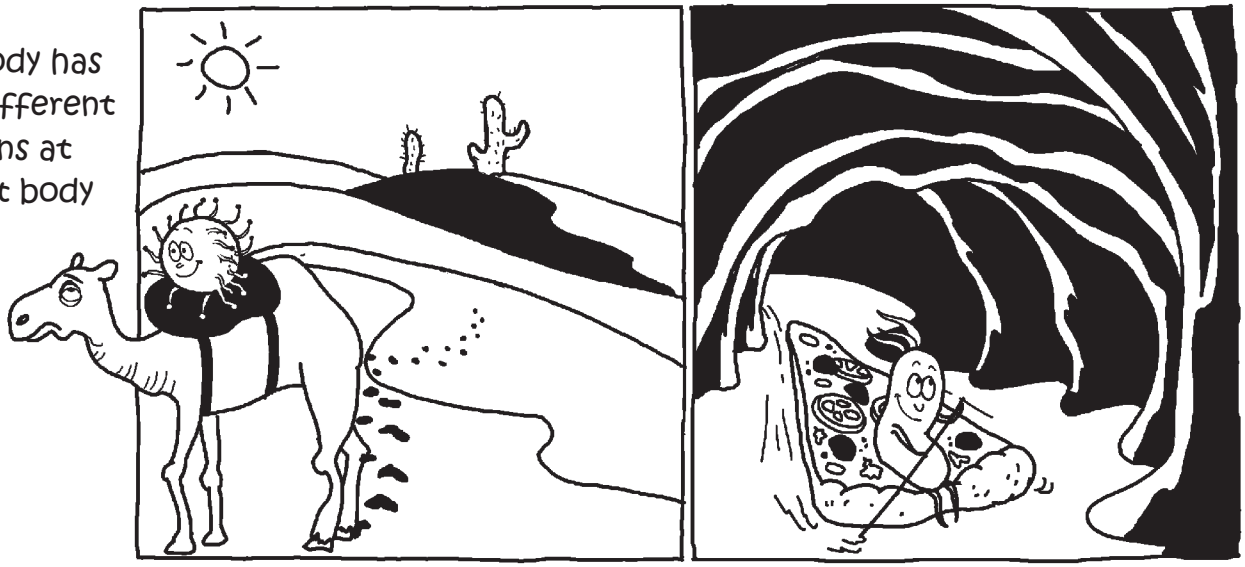


Legendary geneticist and exobiologist (outer space biologist) Joshua Lederberg, recognizing the importance of these microbial communities, coined the term microbiota.

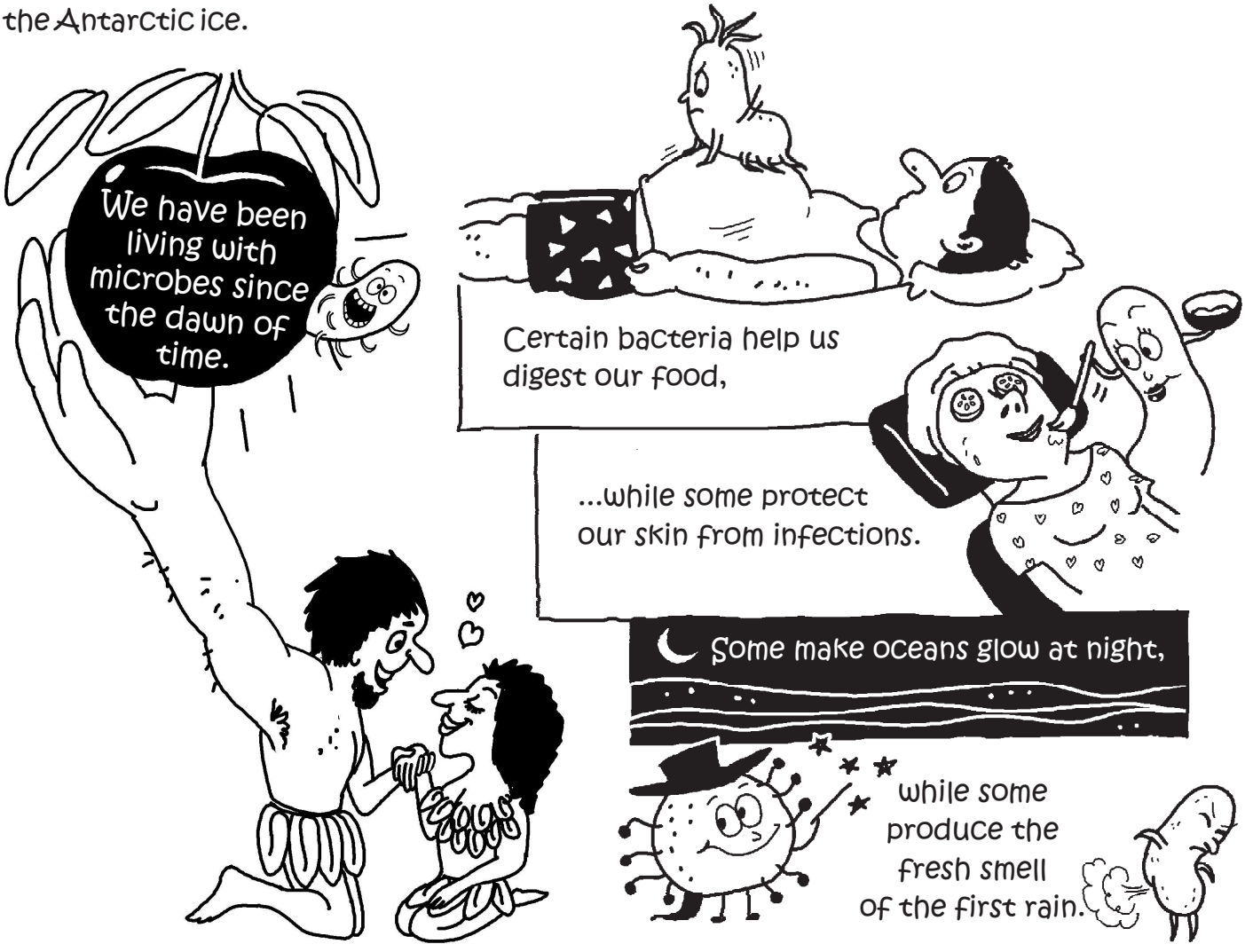
Our body has widely different conditions at different body sites.

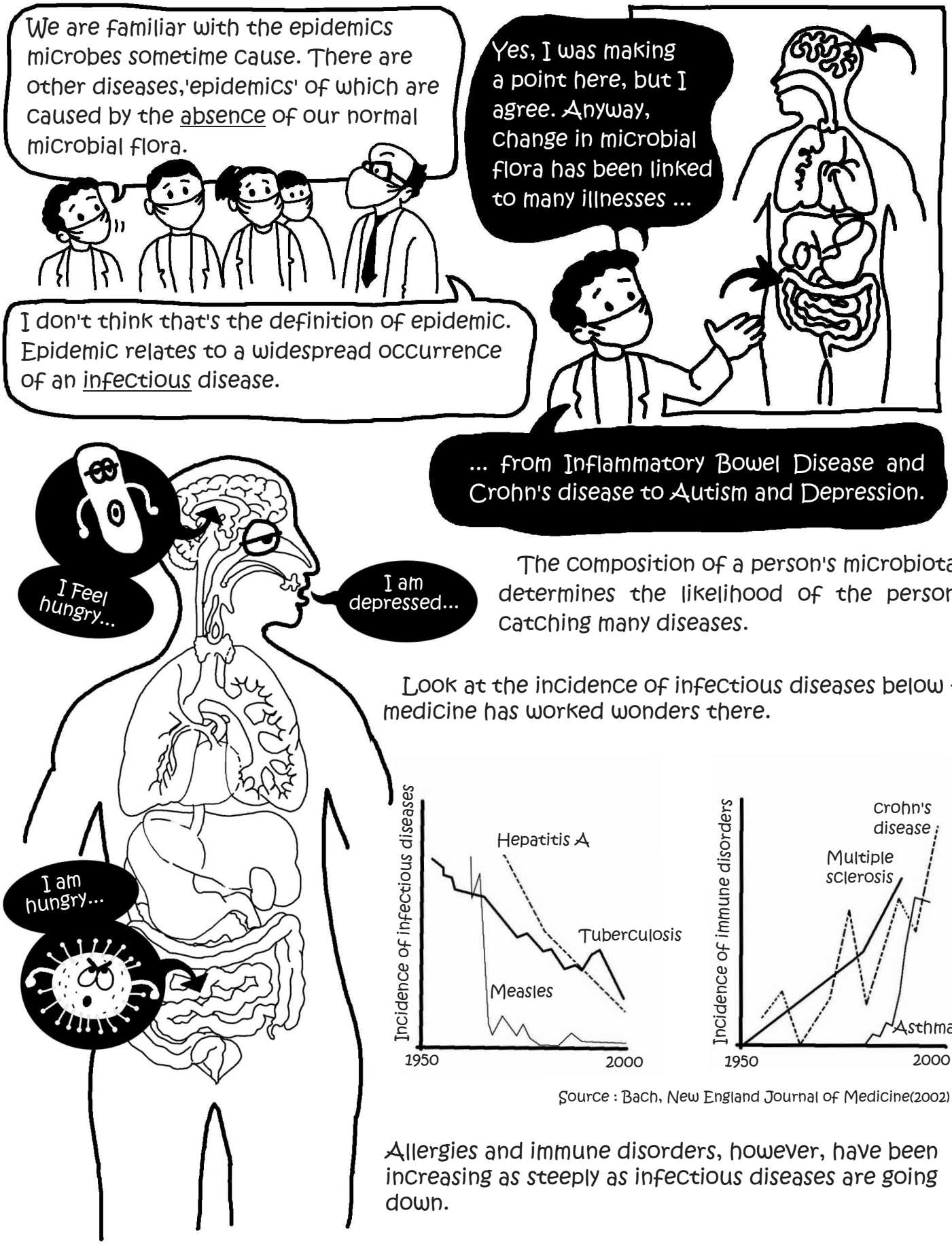
Skin microbes survive in the dry and low-food conditions of our skin.

Stomach microbes live in harshly acidic surroundings.



As a consequence, the microbes that live in these body sites are different, too. As different as those living in the Mammoth Hot Springs to the ones deep under the Antarctic ice.





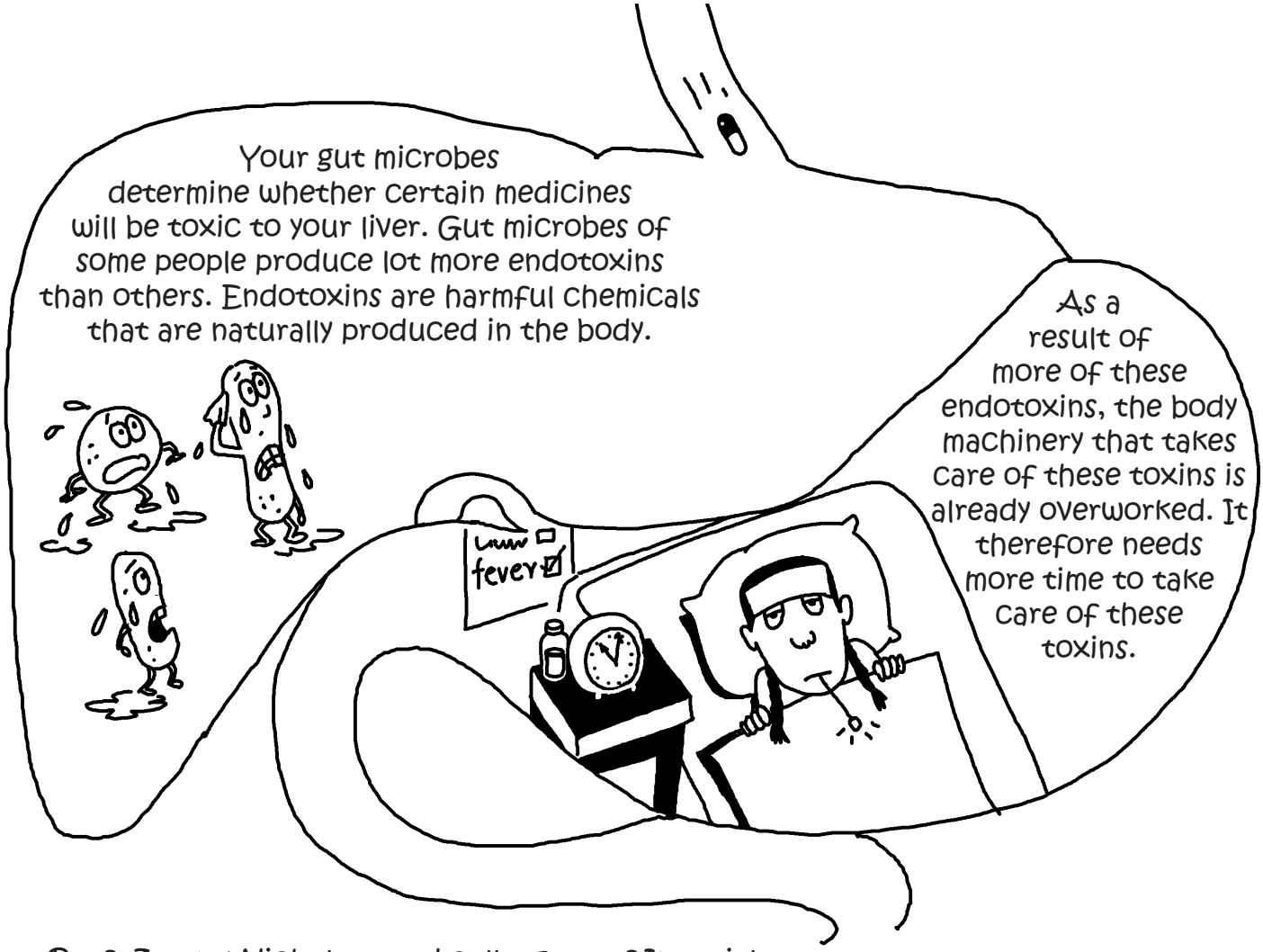
The composition of a person's microbiota determines the likelihood of the person catching many diseases.

Look at the incidence of infectious diseases below -- medicine has worked wonders there.

Source : Bach, New England Journal of Medicine(2002)

Allergies and immune disorders, however, have been increasing as steeply as infectious diseases are going down.

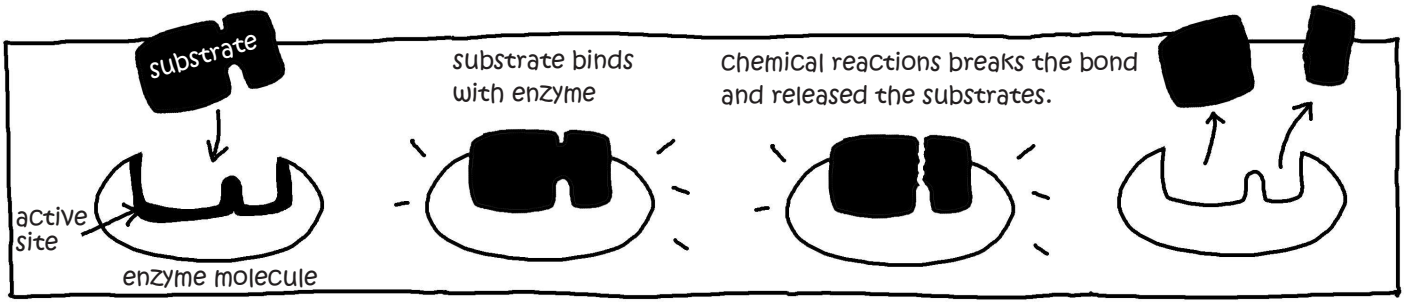
The 'Liver'age microbes have

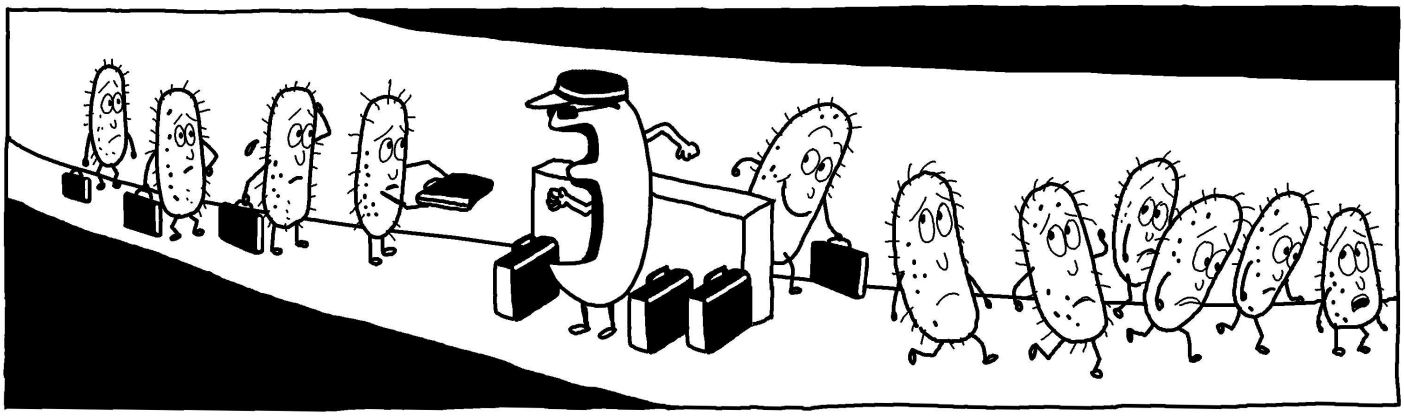


Prof. Jeremy Nicholson and colleagues of Imperial College London found this happening with tylenol. Tylenol is an over-the-counter pain medication.

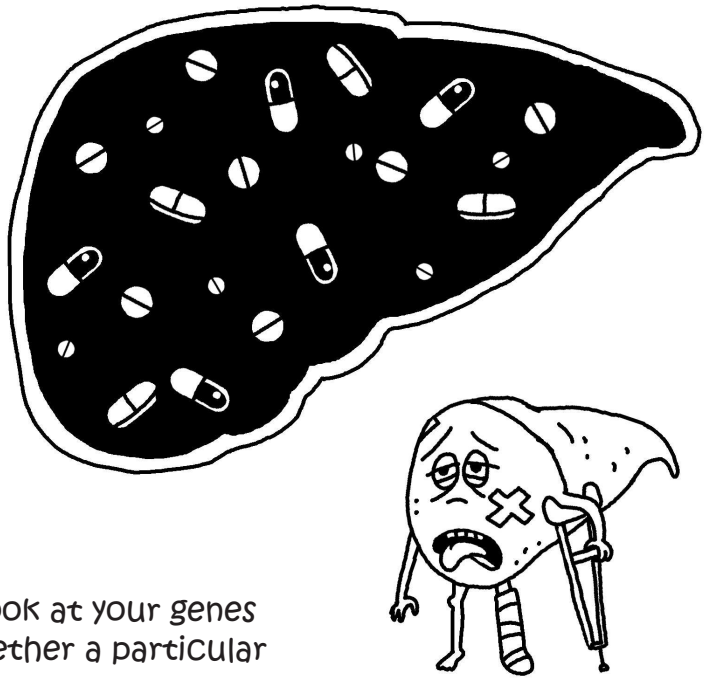
Tylenol might be toxic to a person's liver, depending on the community of microbes that lives in the person's gut. Some enzymes (protein molecules that carry our the chemical reactions in our body) degrade these chemicals.

How enzymes work:

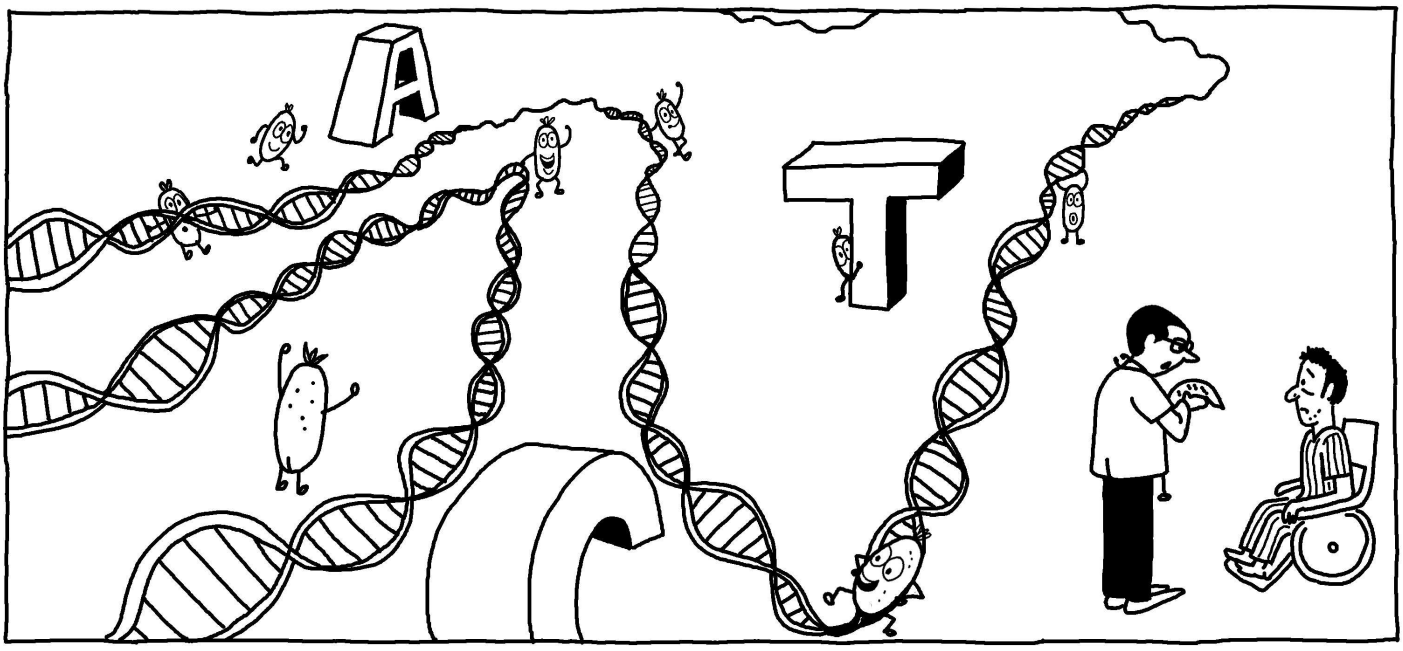




In some people, they were preoccupied with working on chemicals produced by their gut microbes.The enzymes got around to degrading tylenol later, and it remained in the body longer. This turned out to be harmful to liver, which handles degradation of harmful substances.

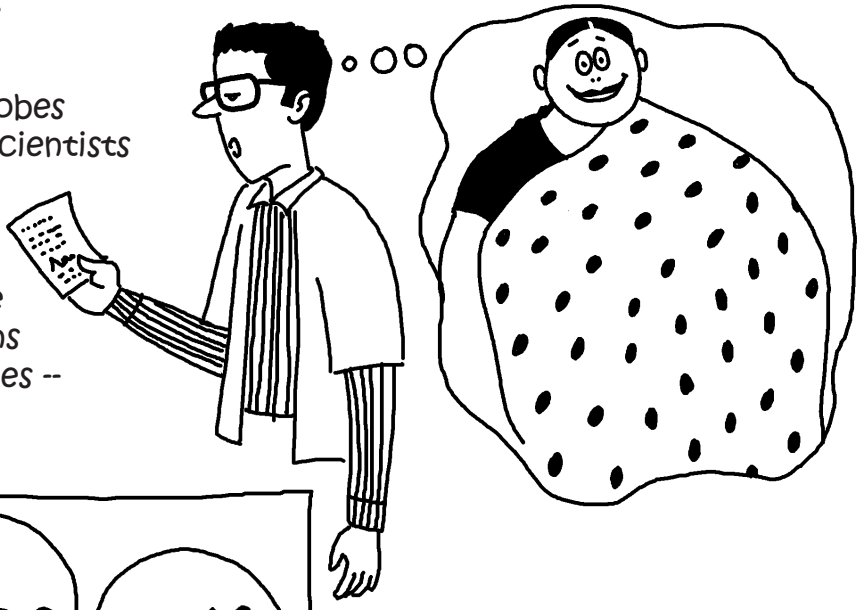


Sometime in the future, doctors can look at your genes and your microbes, and they will know whether a particular treatment will work for you.

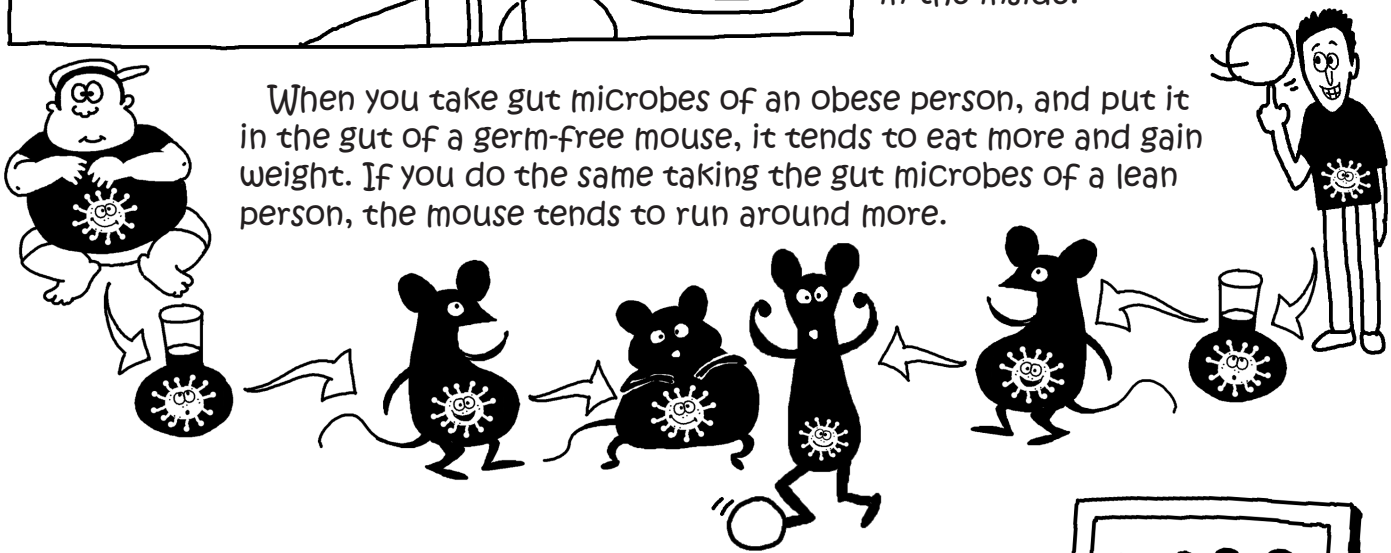


Gut feelings

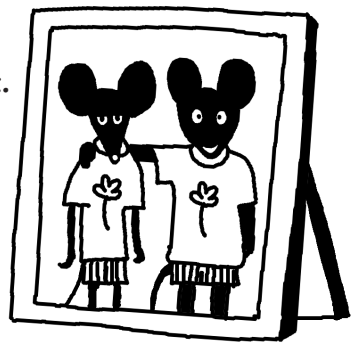
Looking at the microbes present in your body, scientists can predict whether you are lean/obese with 90% accuracy. Now compare it to the accuracy of predictions based on your <u>own</u> genes -- just about 58%.



What's more, scientists can test this on laboratory mice. It's possible to raise germ-free animals in lab, animals which don't have microbes living in or on their body. Such animals are raised in isolators, carefully keeping the conditions germ-free in the inside.



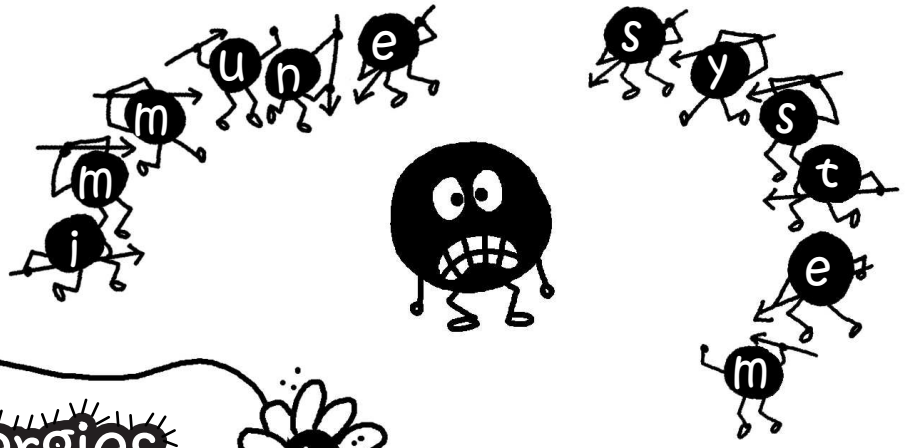
When you take gut microbes of an obese person, and put it in the gut of a germ-free mouse, it tends to eat more and gain weight. If you do the same taking the gut microbes of a lean person, the mouse tends to run around more.

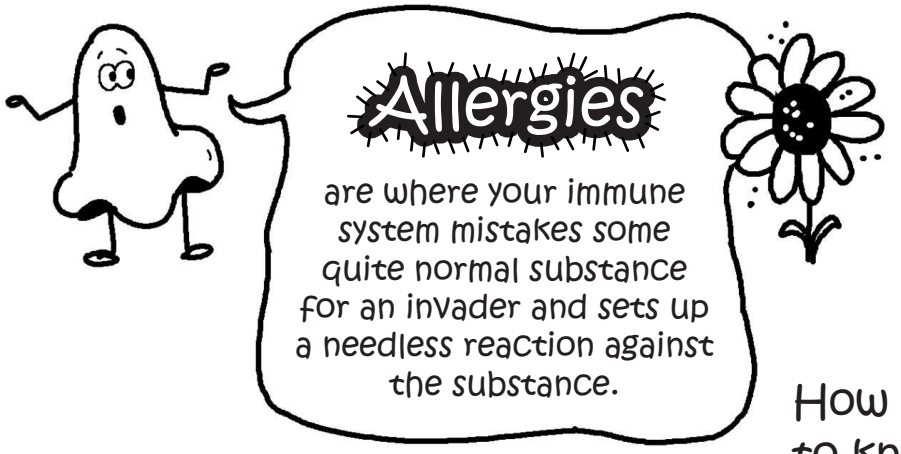


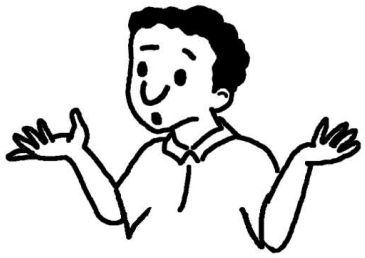
Prof. Jeffrey Gordon and colleagues did an amazing experiment. They took gut microbes of Malawian twin pairs. In these, one twin had nutritional disorder (Kwashiorkor) while the other twin was healthy. Then they populated gut of germ-free mice with the microbes from these twins.

When they put gut microbes of the malnourished twin, the mice grew to be underweight. The mice that got the microbes of a healthy twin did much better.

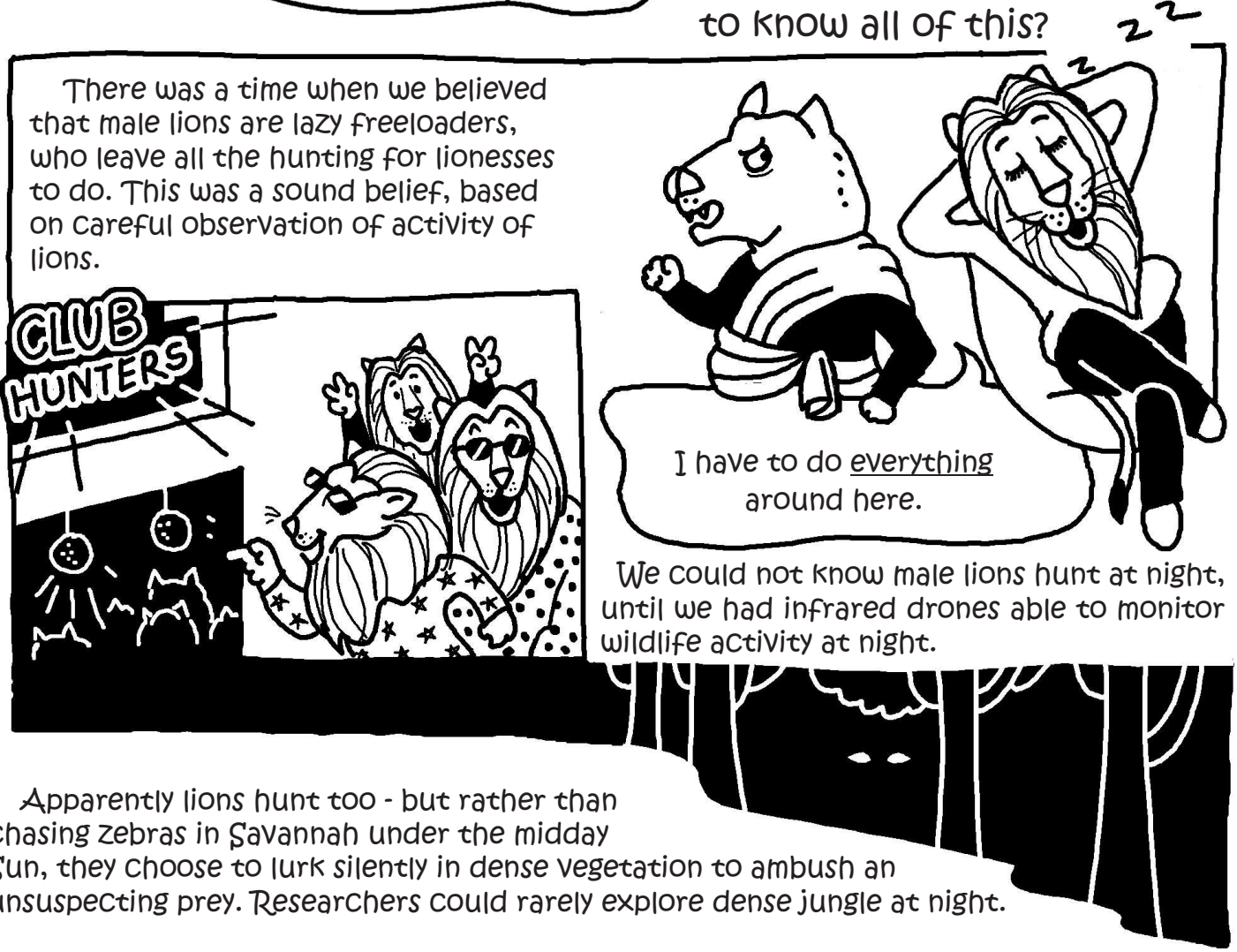
Sometimes, your immune systems mistakes your own body cells for foreign invader cells, and attacks your body cells. These disorders are called autoimmune disorders, because the greek prefix 'auto-' means 'self'.





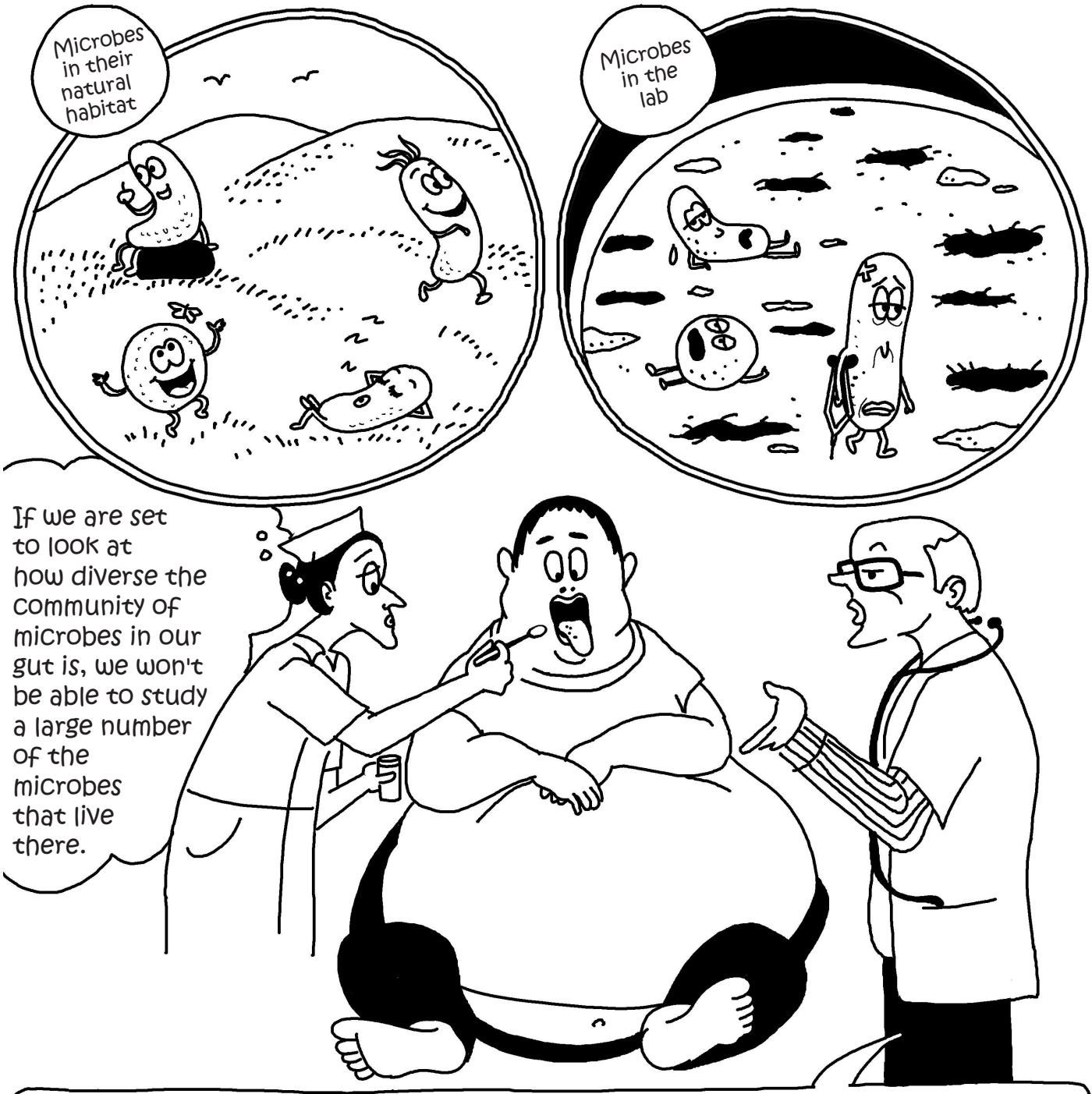


How have we came to know all of this?



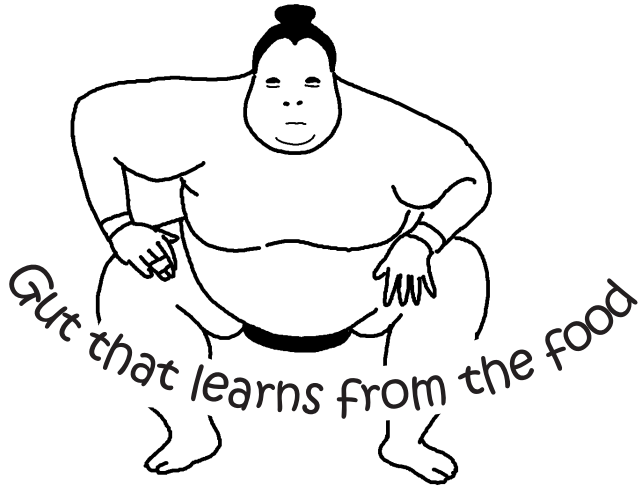
Apparently lions hunt too - but rather than chasing zebras in Savannah under the midday Sun, they choose to lurk silently in dense vegetation to ambush an unsuspecting prey. Researchers could rarely explore dense jungle at night.

Scientists witnessed something similar in microbiology a large fraction of microorganisms can't be cultured in an artificial medium in laboratory. Estimates of the fraction vary, but most of them are over 90%. We can't study a very large number of microorganisms by traditional methods even now.

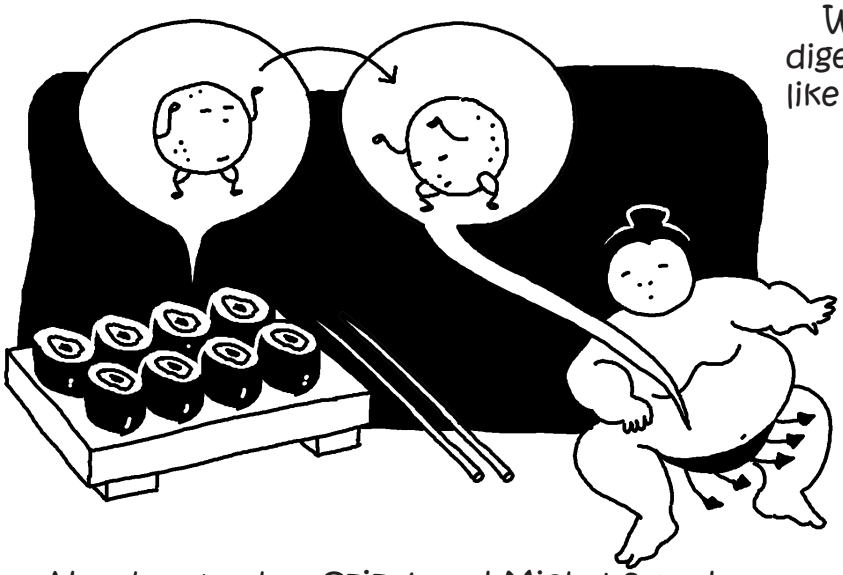


We will end up underestimating the number of species. By genomic sequencing, on the other hand, we get much better estimates. Genomic sequencing identifies the sequence of letters on DNA, the molecule of heredity. Scientists can identify the unique markers of each species from the DNA extracted from, say, someone's mouth.

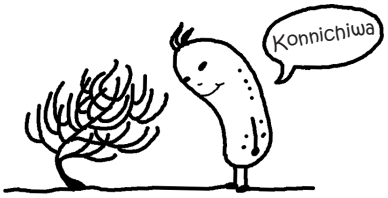
What is beginning to unravel from this investigation is a fascinating tale of interaction, communication and deception between microbes and humans.



Professors Mirjam Czjzek, Gurvan Michel and colleagues of Pierre and Marie Curie University found that gut microbes can learn the art of digesting the food from the bacteria in your food.



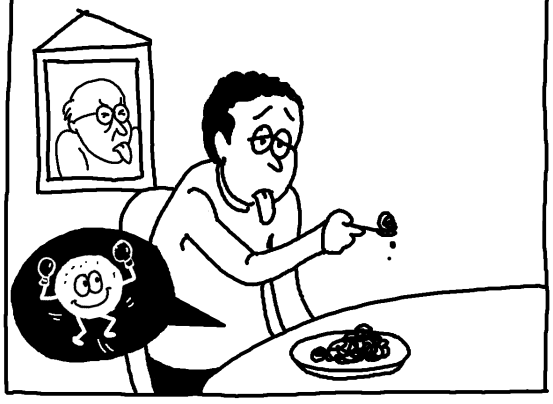
Now here's what Czjzek and Michel found: In Japanese population, a red algae is a common ingredient in the diet, and is used to prepare sushi.



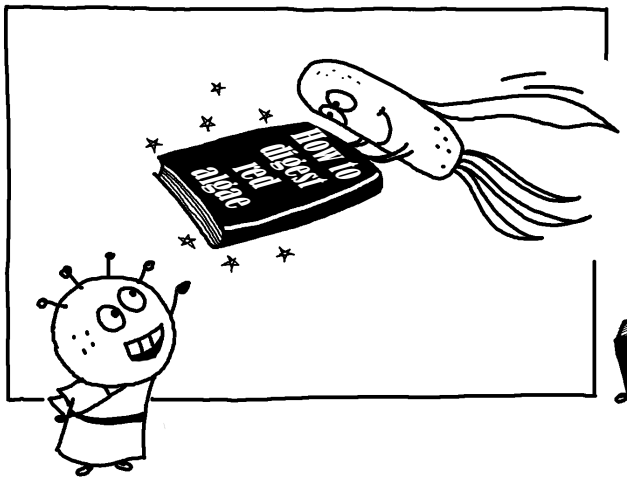
The gut microbes in Japanese population have the ability to degrade the carbohydrates present in the red algae. The gut microbes of North American individuals don't.

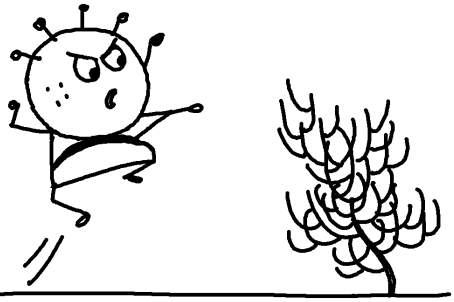
We rely on our gut microbes for digesting long chain polysaccharides like starch and cellulose in our diet.

We don't have the genes required for the task in our own genome, while the gut microbes do have the genes that encode enzymes called Carbohydrate Active Enzymes (CAzymes). These help us utilise the carbohydrates from terrestrial plants in our diet.



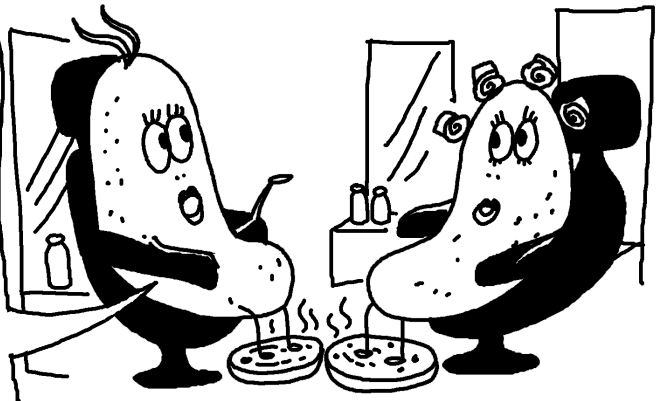
The genes that encode these enzymes have been transferred from marine bacteria to Japanese gut microbes. Which makes sense, as the marine bacteria are expert in the craft of digesting these marine red algae.



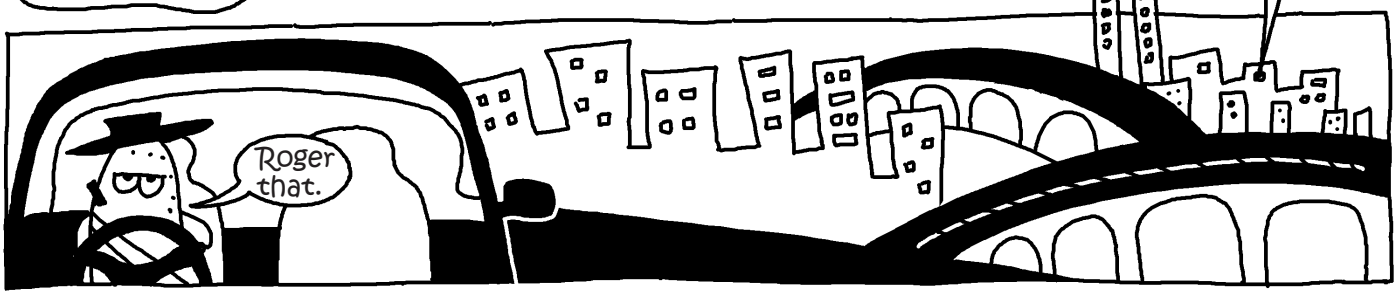


Things like this are possible in bacteria because of their huge gossip network. Unlike us, bacteria of different species are able to transfer genes to each other.

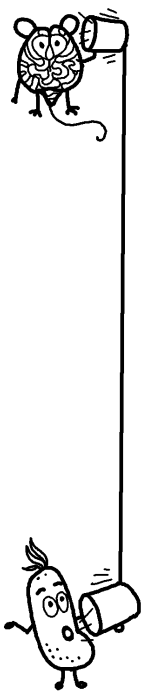
There is a new antibiotic in use, that attacks our cell walls, and <u>this</u> is what you need to know to counter it.



There is a rare complex carbohydrate, so not everyone needs the ability to digest it, but apparently there is some in food these days, and <u>this</u> is how you digest it.

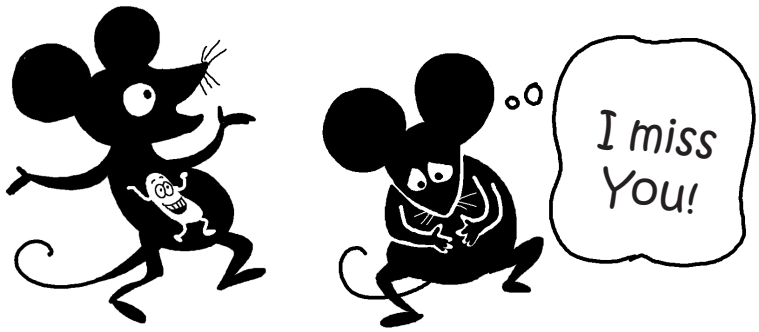


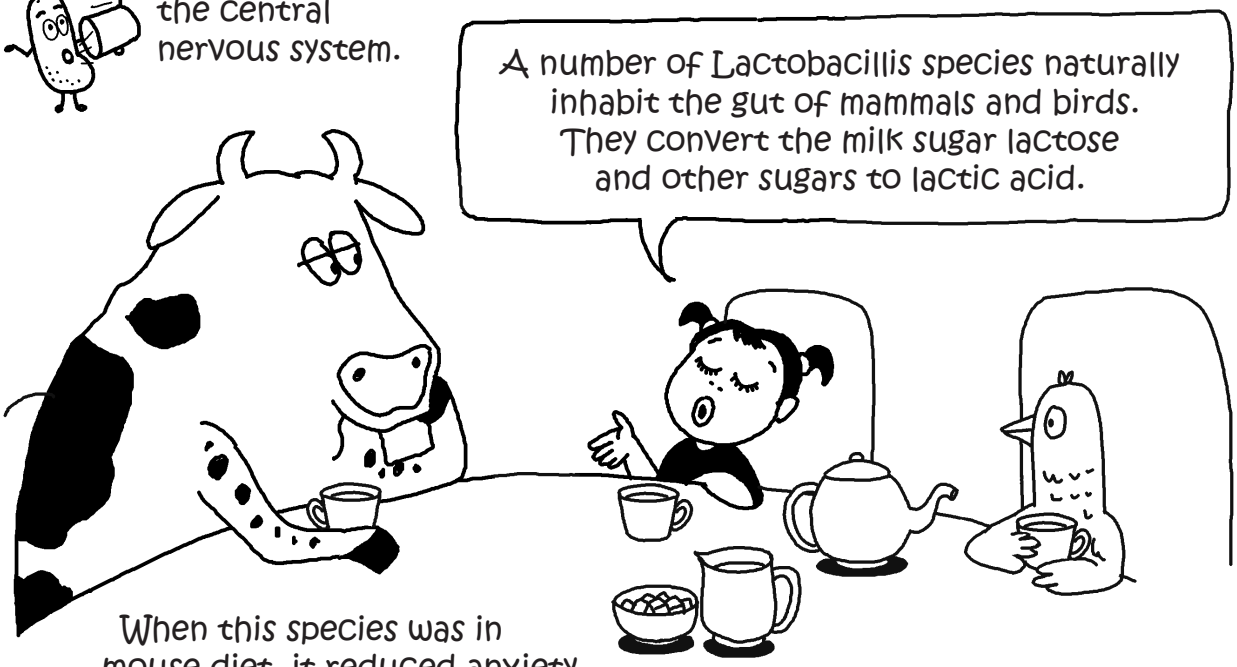
Here's another interesting thing about gut bacteria.
When you feel hungry, who exactly is hungry?
Is it only that your body cells need food?
Not really.



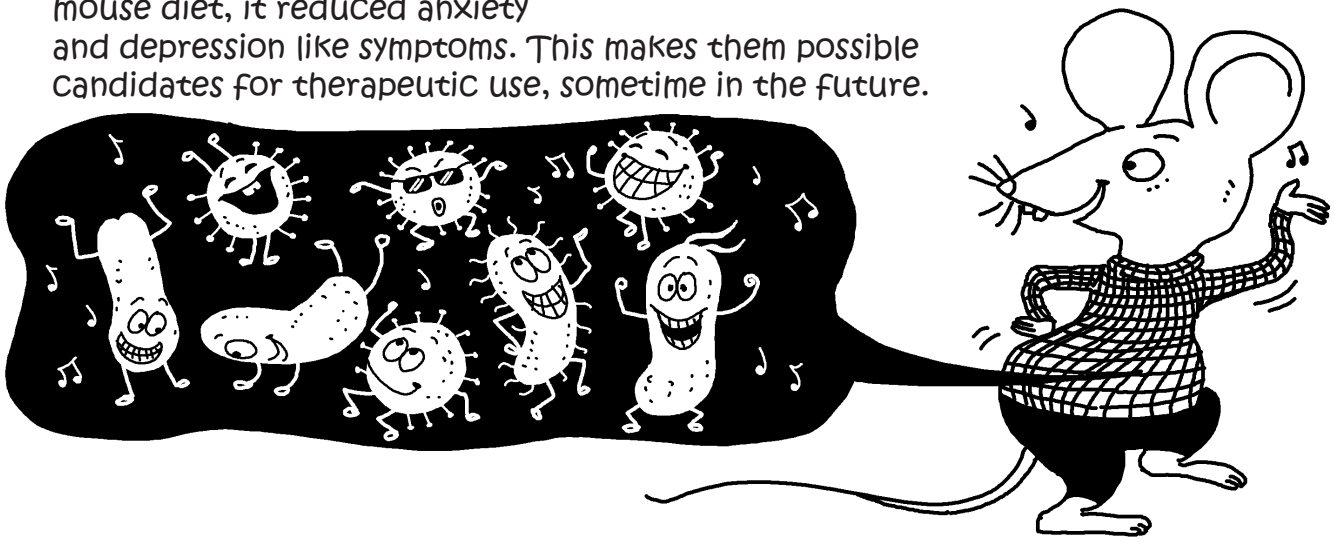
Prof. John F. Cryan and colleagues of the University College Cork found that a bacterial species in mouse gut was able to communicate with its brain. It did so directly through the vagus nerve of the central nervous system.

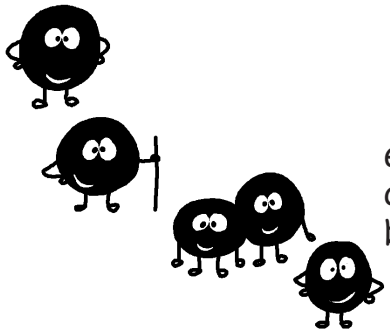
The bacterial species that they experimented with was Lactobacillus rhamnosus. They saw that Lactobacillis could change emotional behaviour of mice.





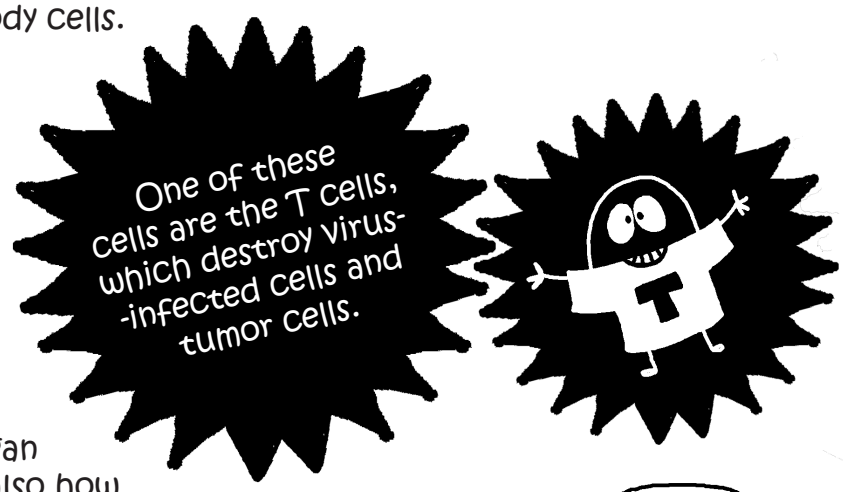
When this species was in mouse diet, it reduced anxiety and depression like symptoms. This makes them possible candidates for therapeutic use, sometime in the future.





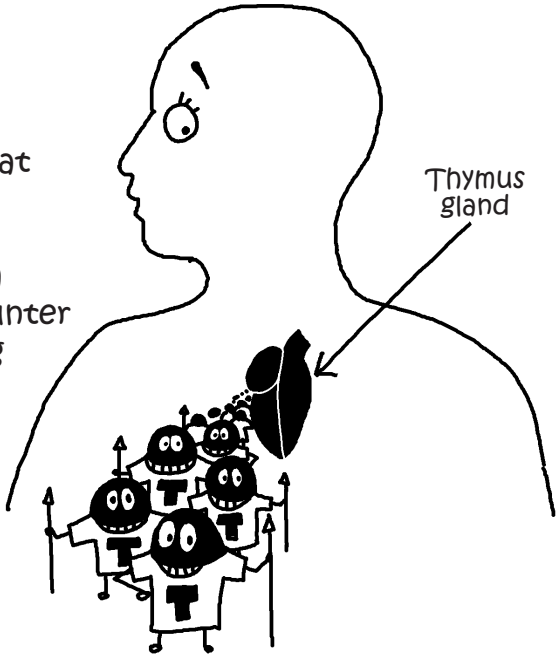
'Us' and 'Them'

Our immune system protects our body by identifying foreign entities. Except in cases of a few disorders, called auto-immune disorders,our immune 'police force' cells do not attack our own body cells.

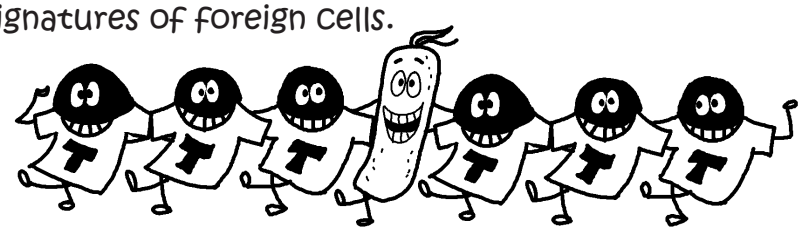


T cells develop in an organ called thymus, and that's also how they got their name.

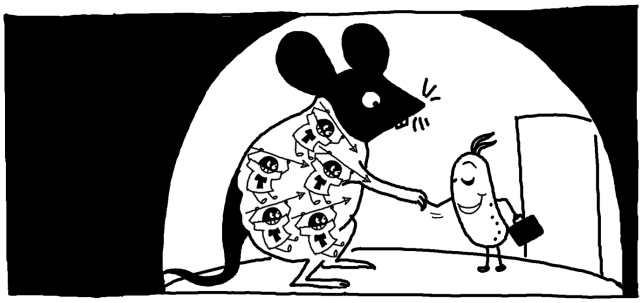
In thymus, chopped proteins from all over the body are presented to T cells. The T cells that target these are removed, and only those are kept that do not target our body cells.



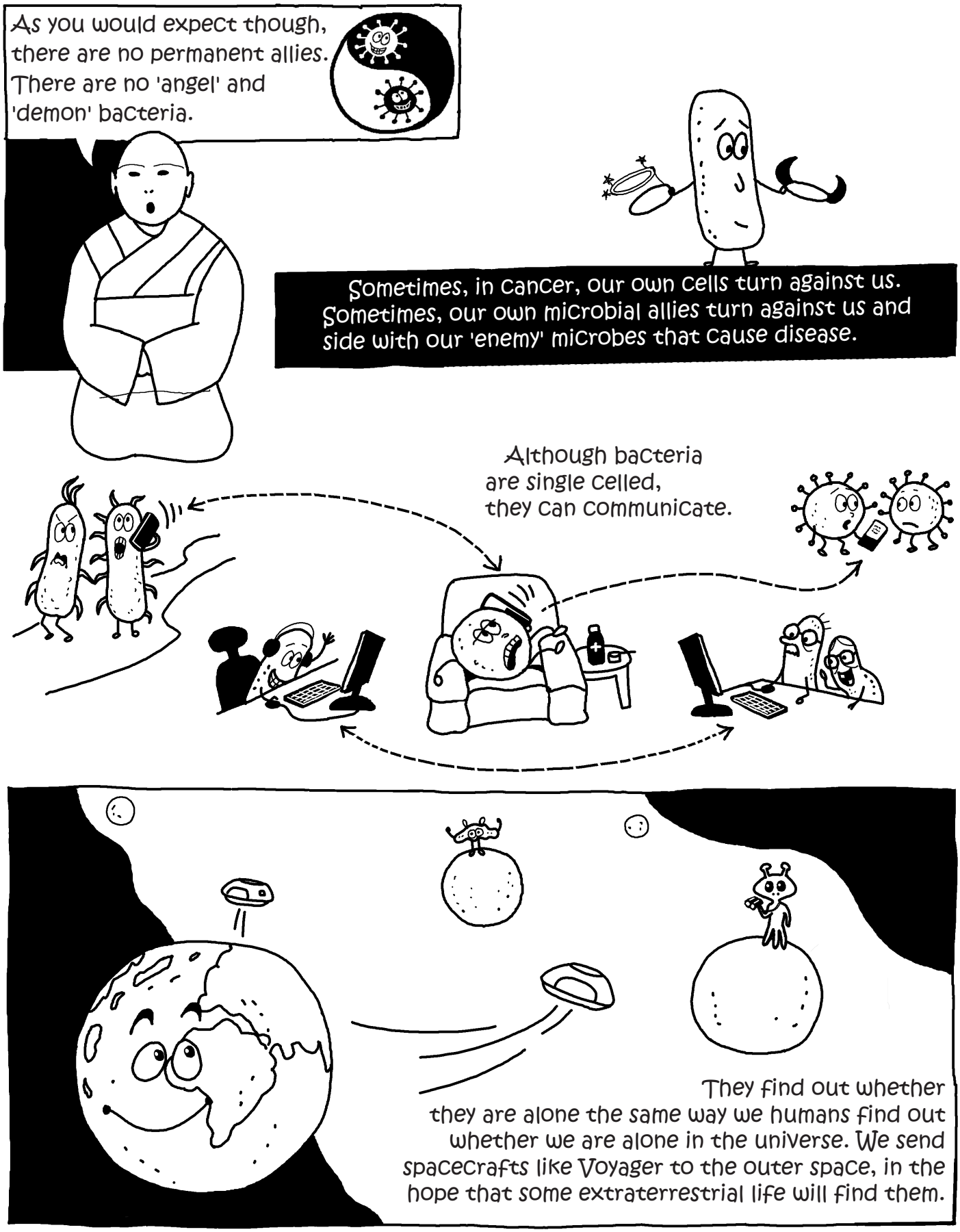
The signatures presented to T cells are made from chopped protein molecules that they will likely encounter in our body. They are trained to recognize everything that they do not encounter in their training as signatures of foreign cells.

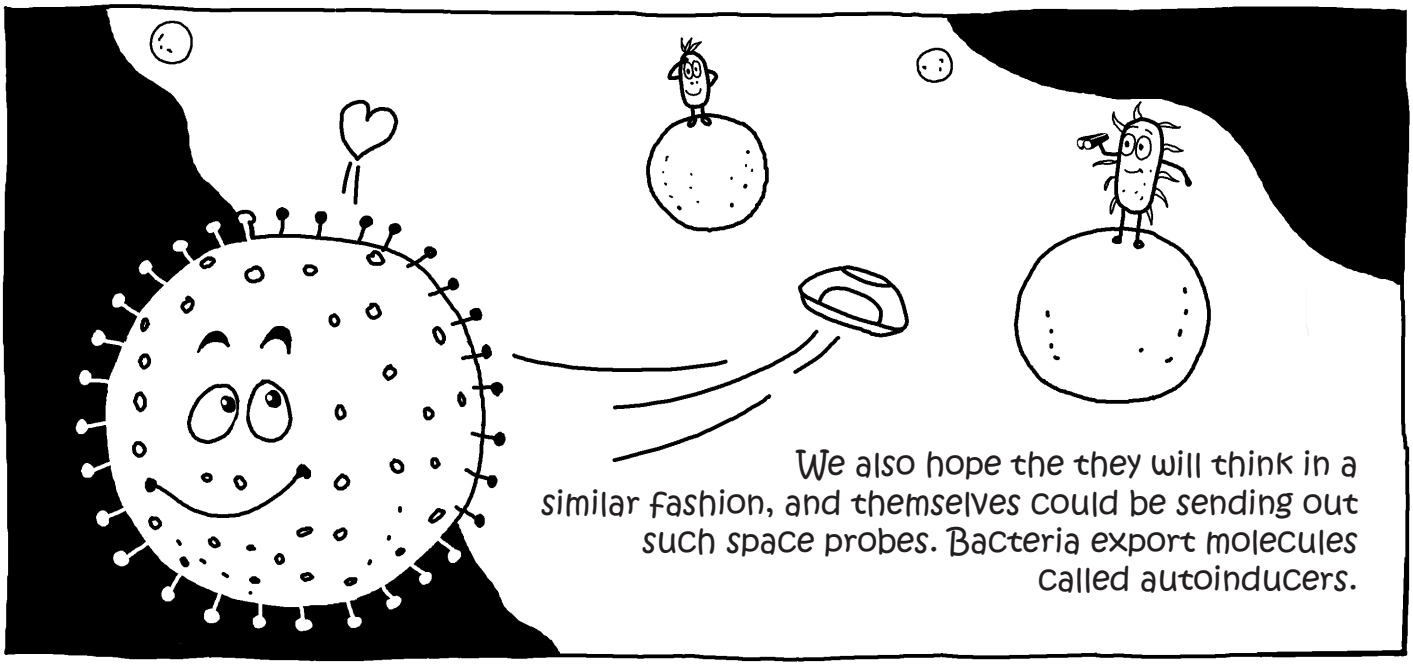


What's interesting, they are also taught to tolerate our gut microbes, to treat it as one of 'our own' cells. Evolution seems to have recognized the advantage of immune system knowing the friendly microbes.



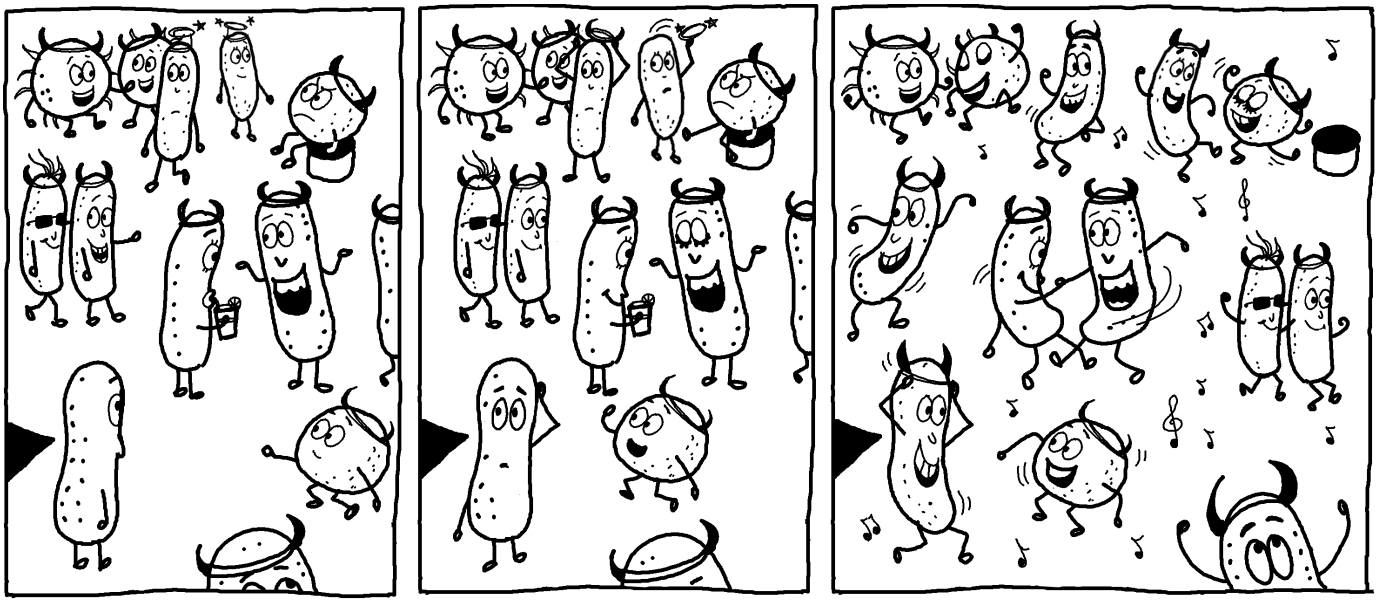
The immune system of mice, that are raised in germ-free environment, doesn't get a chance to learn what do friendly microbes look like. When these microbes are introduced in mice later in life, they are attacked by the immune system of mice.


As you would expect though, there are no permanent allies. There are no 'angel' and 'demon' bacteria.
Sometimes, in cancer, our own cells turn against us. Sometimes, our own microbial allies turn against us and side with our 'enemy' microbes that cause disease.
Although bacteria are single celled, they can communicate.
They find out whether they are alone the same way we humans find out whether we are alone in the universe. We send spacecrafts like Voyager to the outer space, in the hope that some extraterrestrial life will find them.



These molecules move around in a random fashion in the surroundings (what scientists call diffusion).

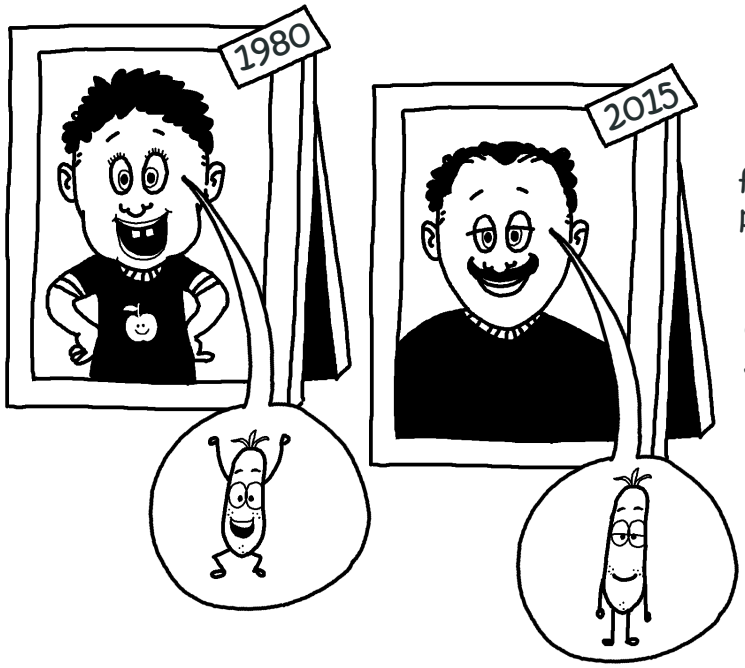
Depending on the number of bacterial cells around them, a particular number of autoinducers enter back in the cell.



Bacteria can guess the number of 'their' people around them, and decide their behaviour accordingly. This lets disease causing microbes strike when their numbers are high enough.

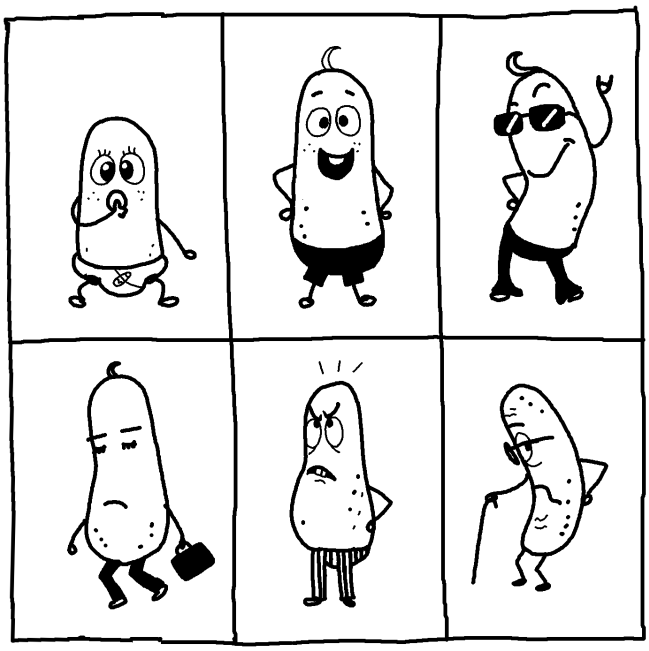
When you wash your hands, you wash away all this dirty politics.

Skin Changers



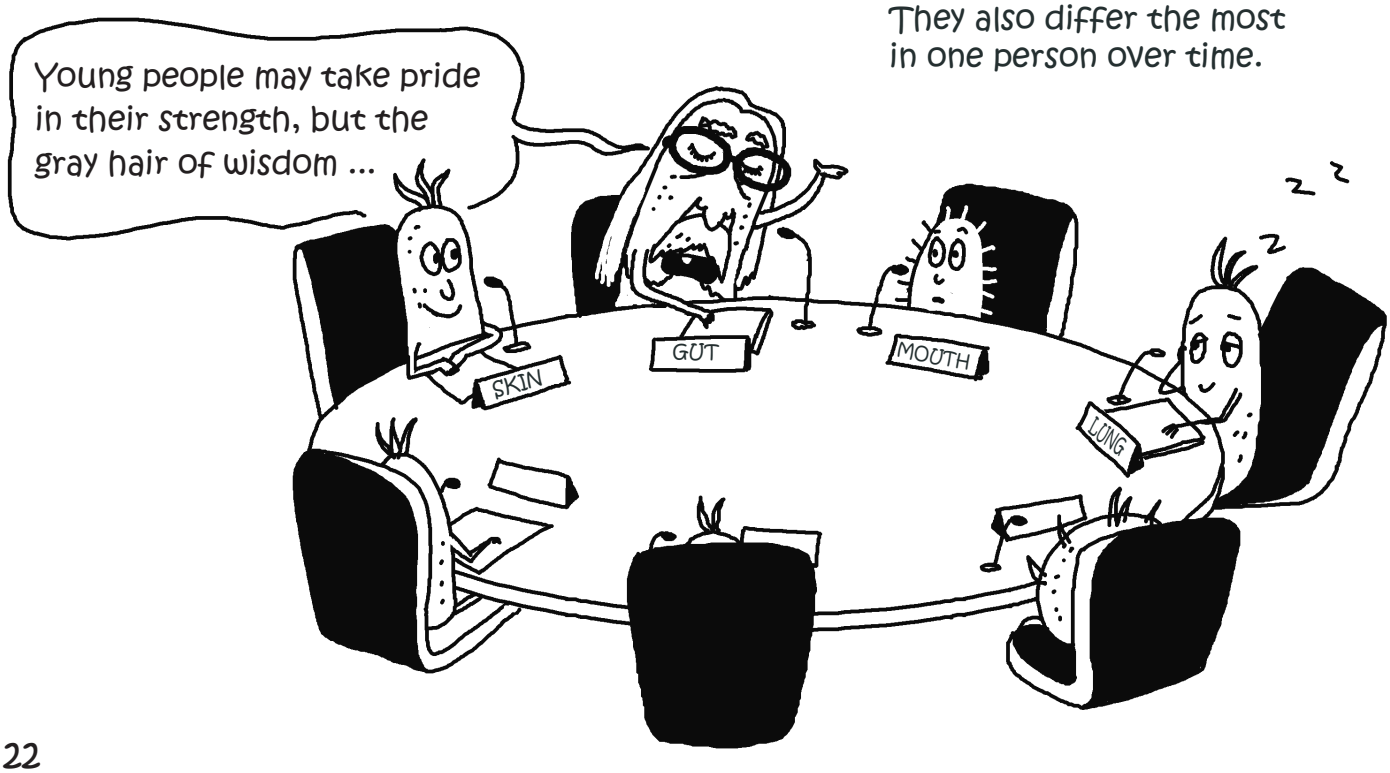
The microbial landscape isn't the same for everyone. Neither is it constant in one person over time.

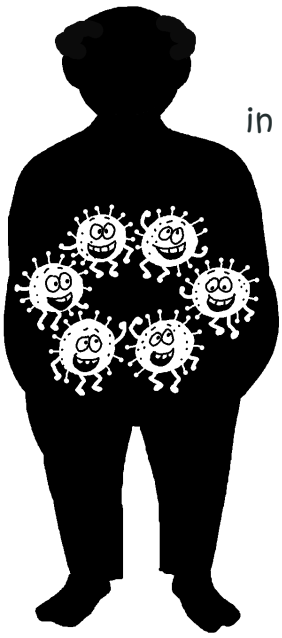
The community of microbes residing in a person's body is forever shifting its structure.



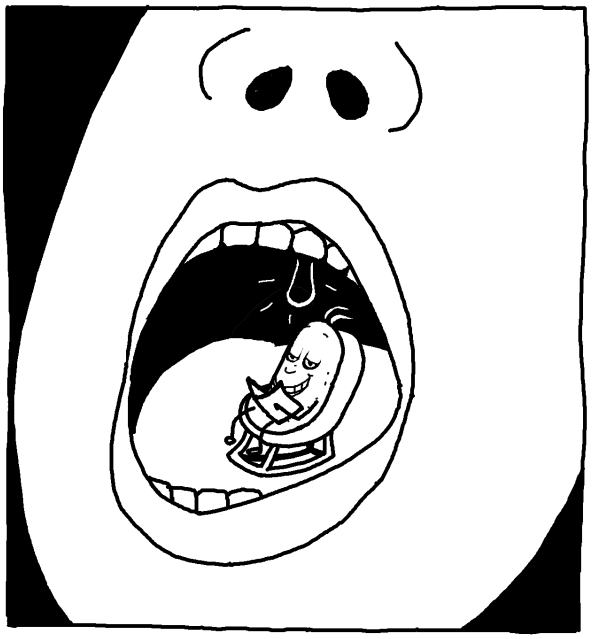
Among the different body sites, skin microbes are the most different from one person to another.

They also differ the most in one person over time.





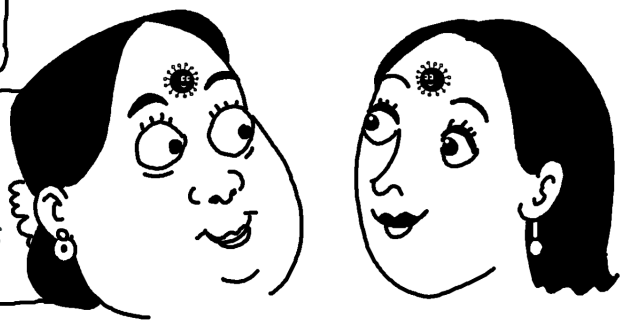
Gut microbes are different in different people, but the gut community tends to be stable.It doesn't vary much over time in a single person.



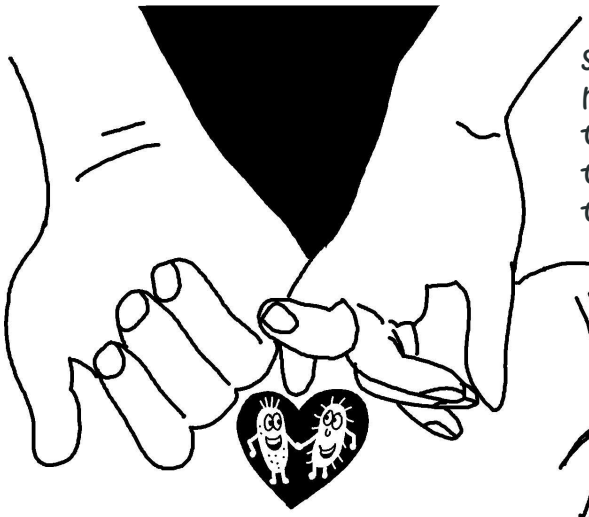
The microbes in mouth remain the most similar, both in person-to-person and in one person over time.

Skin itself doesn't have the same microbes everywhere. Skin is our largest organ. We have around 22 square feet of it. There are some moist areas, some dry areas. As with other body sites, different skin sites have their own set of microbes.

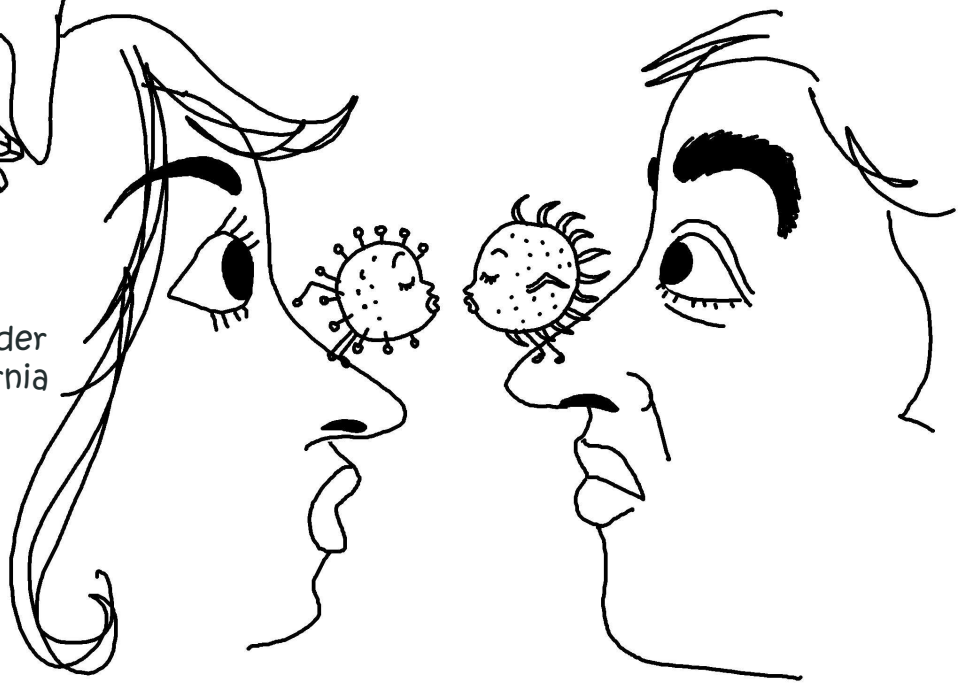
If you look at the skin microbes of two different people, here's what you will find. Microbial community on person A's forehead is more similar to microbial community on person B's forehead, than to that of person A's hand.



If you compare palm microbes of A and B, however, you can see they are different from one person to another.



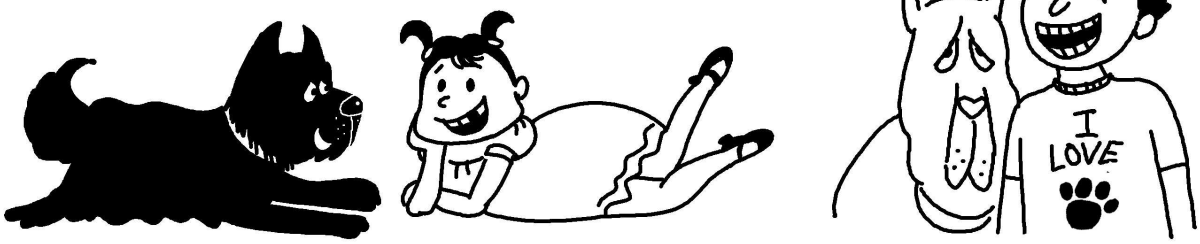
The person-to-person variation in different skin sites varies depending on the skin sites, too. The microbes on our toe webs, hand webs, armpits, navel tend to be very different in different people, while the microbes on backs, nasal creases tend to remain the same.



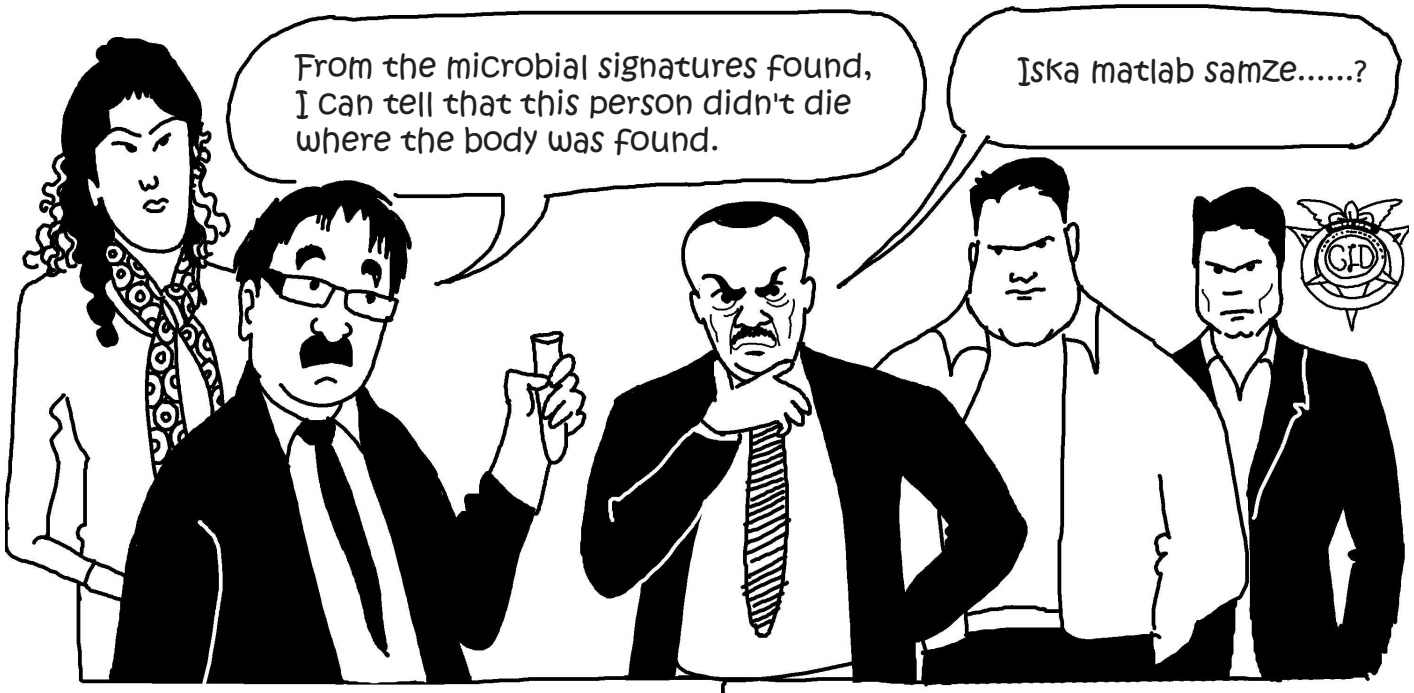
Prof. Rob Knight's lab at University of Colorado Boulder (now at University of California San Diego) looked at the microbial landscape in families that had a pet dog, and those that didn't.

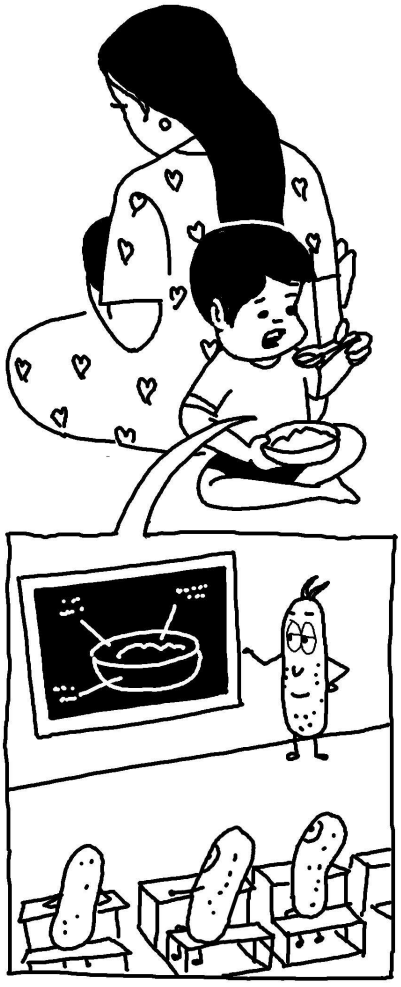
What he found was interesting. People who live in the same household share larger part of their microbes with each other than they do with strangers. Especially so for skin microbes.

Having a dog results in more sharing of microbes between the members of the families. People share more microbes with their own dog than with a stranger's dog, and you can match the dog with the family based on it's microbes.

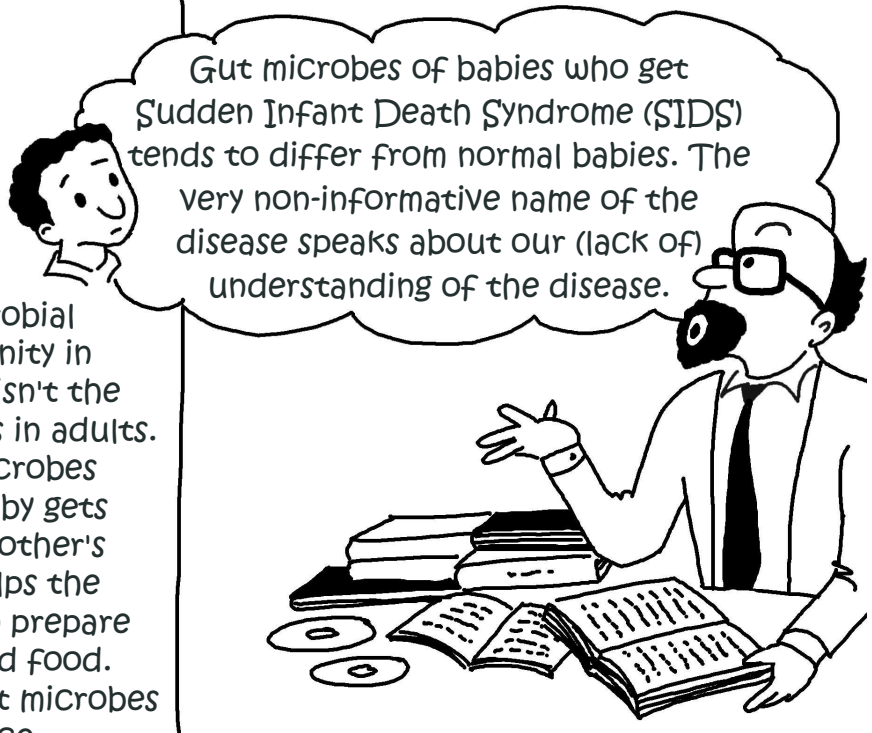


Forensic examiners will be able to use this variation to solve crimes, not far in the future. The way fingerprints are used to identify a crime suspect, the microbial prints of people can be used too. Detectives will be know a lot about a crime victim, like where he/she lived, based on the microbes in his/her body.

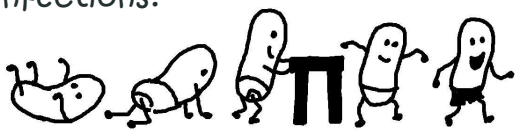




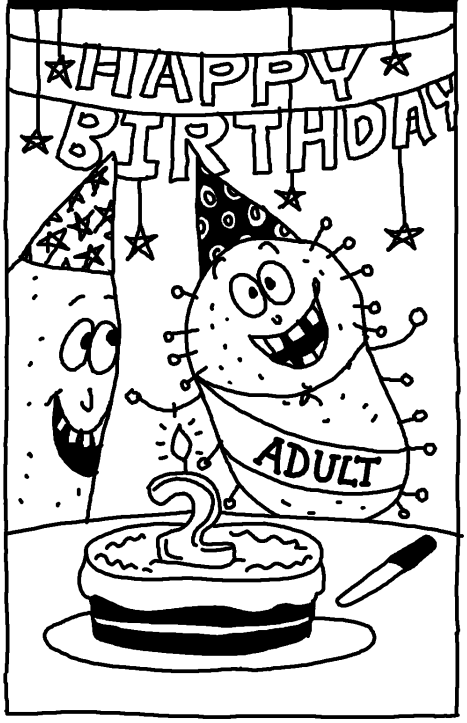
Microbial community in babies isn't the same as in adults. The microbes that baby gets from mother's milk helps the baby to prepare for solid food. The gut microbes influence development of the immune system, and possibly prevent allergies later in life.

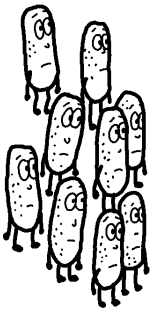


The differences in microbes might be contributing to differing susceptibility to infections.

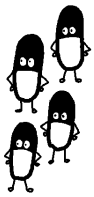


Microbial community of babies start to resemble adult microbes after about two years of age.

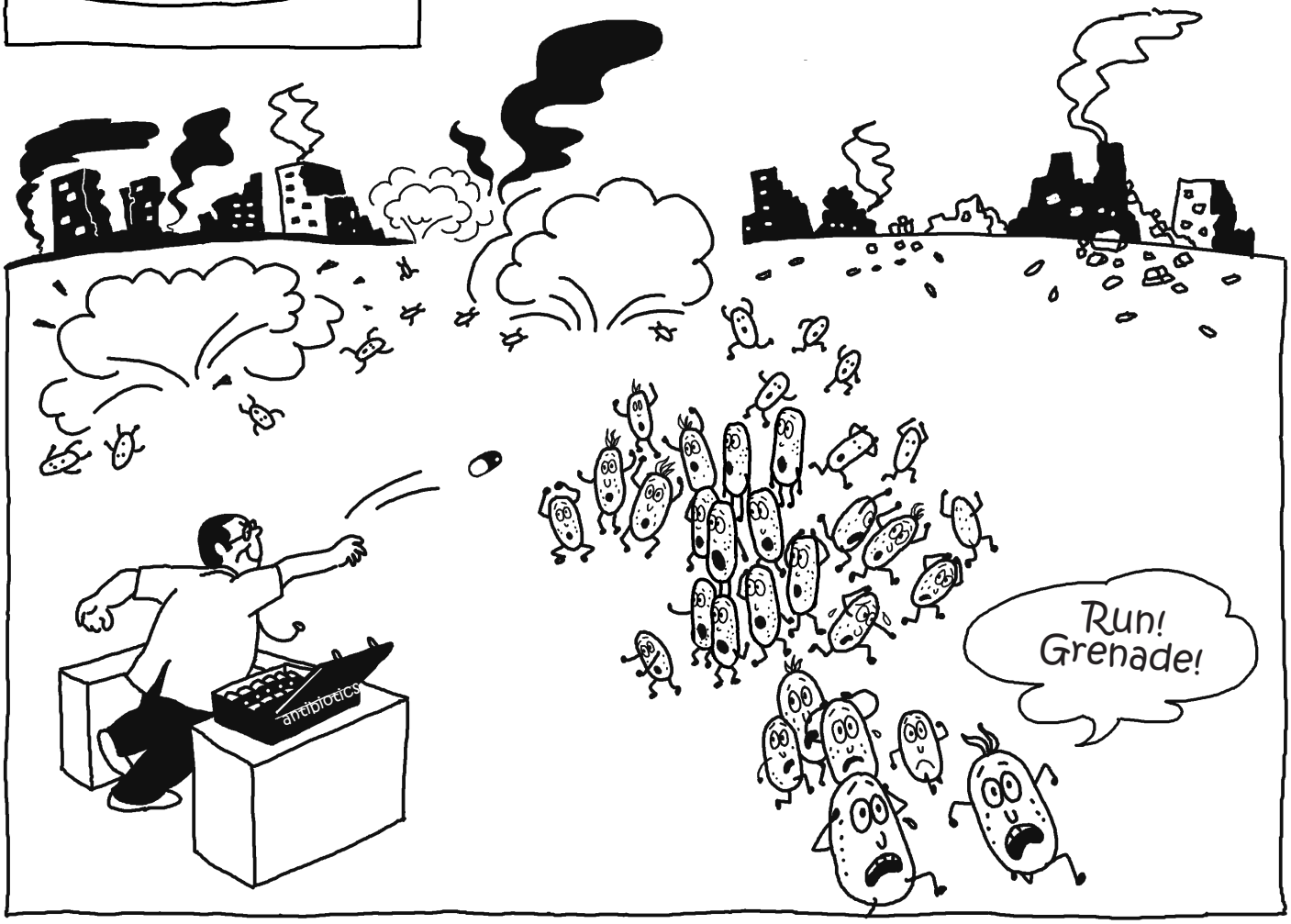




As with any complex community, the community human microbes is at a stable average state. Repeated doses of antibiotics seem to shift it to a different stable state. The consequences of this incomplete recovery of microbes are unknown, and very hard to predict.

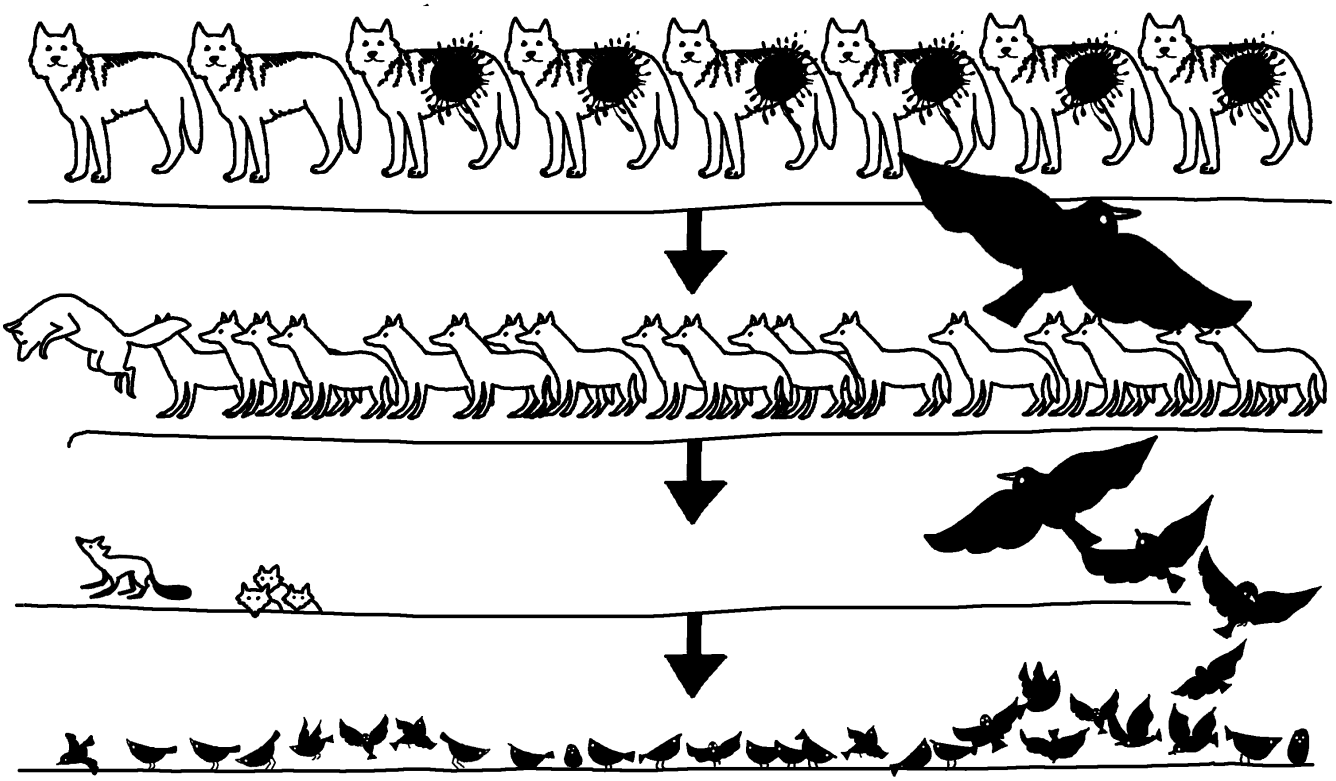


Disclaimer: In no way is this intended to suggest that you shouldn't take antibiotics that are prescribed. Depending on the circumstances, the benefits of antibiotics may greatly outweigh the risks.



This is just like difficulty in predicting effect of extinction of one species on the entire forest.

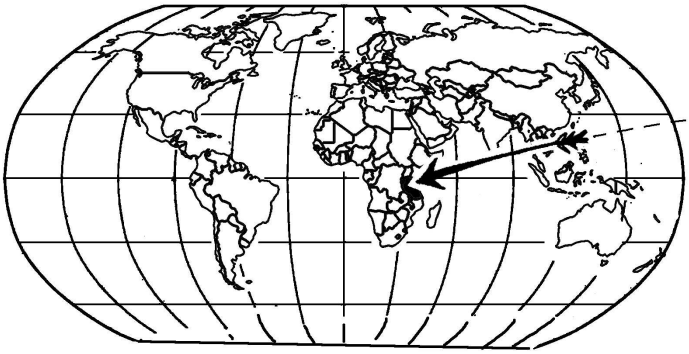
When hunting in Yellowstone National Park had pushed wolves to extinction, elk and coyote population increased. Coyote kill foxes, so when coyote increased, fox population went down. Certain ground nesting birds, that were prey to the foxes, increased.



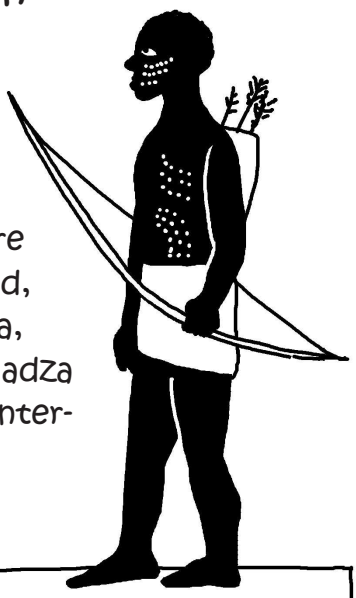
The chain affected many organisms, including fungi and microbes. The conditions of Yellowstone declined to a great degree.

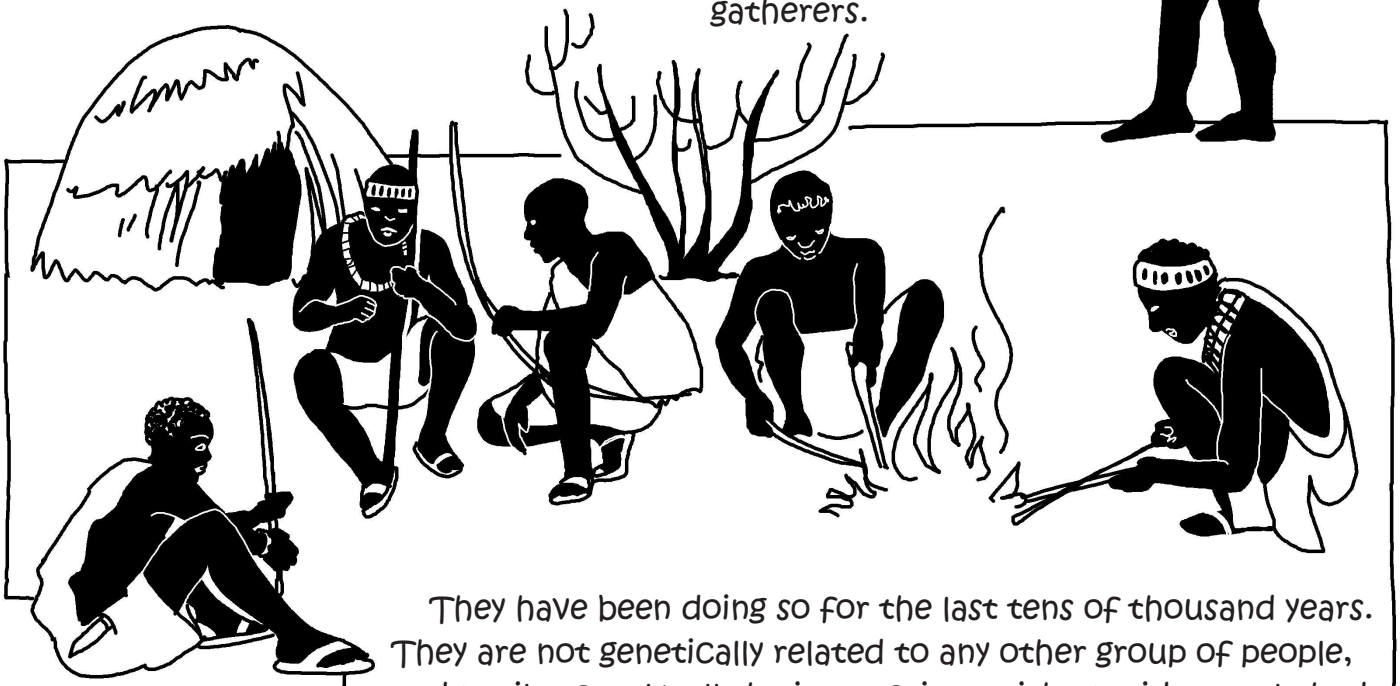
Many efforts to conserve the national park were unsuccessful, until wolves were actually re-introduced. The effect of antibiotics on a community of microbes could be of a similar kind. We need a lot more research before we attempt to predict the effects of altered microbial ecosystem..

Where the Dawn Was Frozen



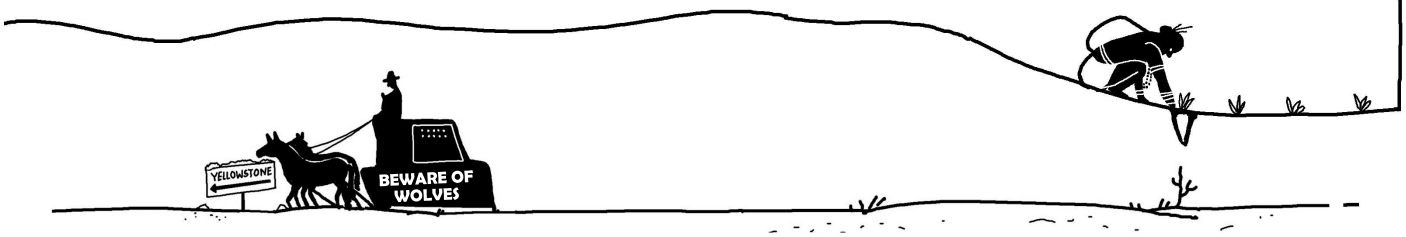
Not far from where the early humans lived, in central-east Africa, a few hundreds of Hadza people still live as hunter-gatherers.

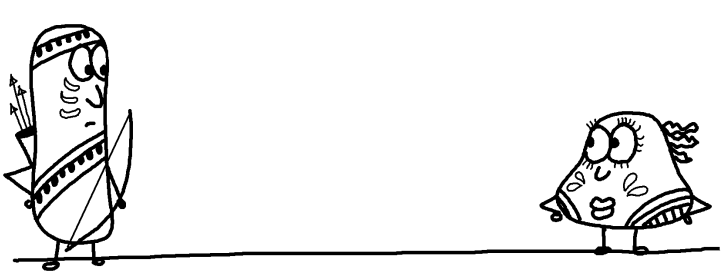




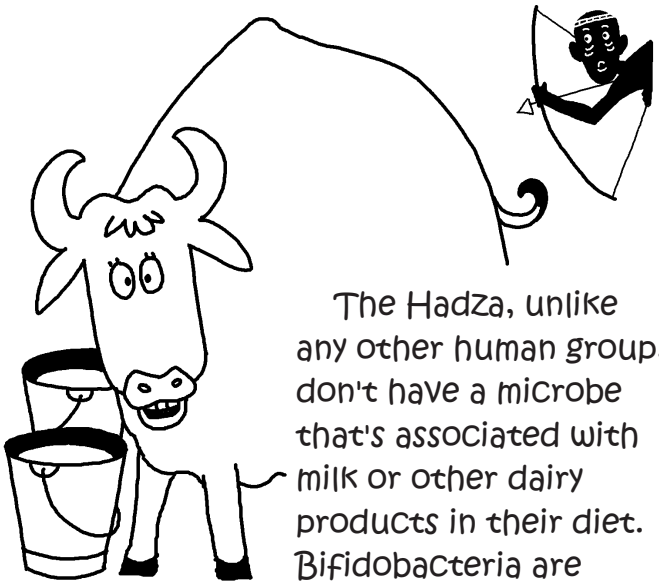
They have been doing so for the last tens of thousand years. They are not genetically related to any other group of people, and until recently, all the interactions with outside people had been hostile. No wind of anything that was invented or discovered in the last 10,000 years reached the Hadza.

Hadza men hunt for food or forage for honey. Women forage for plant food and underground tubers. We humans did the same for 95% of the history of our species. The study of microbes of Hadza people is so exciting, because it might tell us so much about our ancestors.

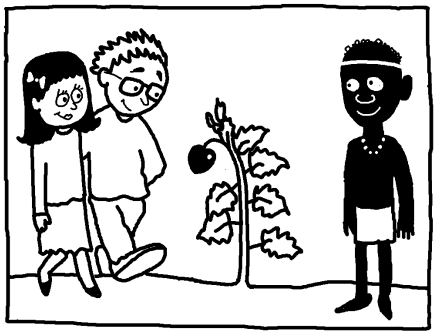


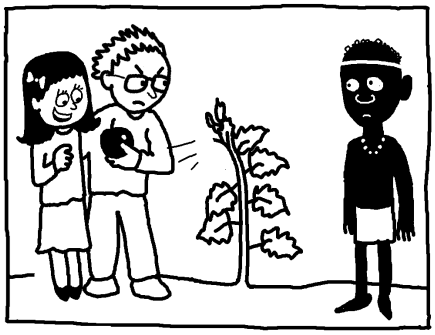


When Prof. Amanda Henry's team studied the gut microbes of Hadza, they found that microbial communities in men and women were very different. This isn't seen in any other human group yet studied.

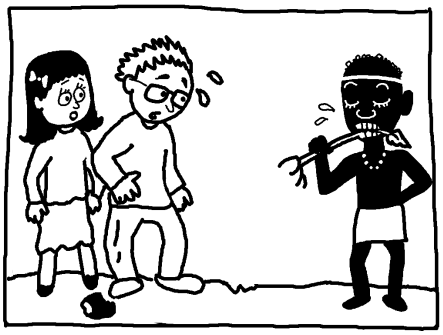


The Hadza, unlike any other human group, don't have a microbe that's associated with milk or other dairy products in their diet. Bifidobacteria are present in all other human populations in infants and adults as well. In adult Hadza, however, they are completely absent. This is significant, though not surprising. Hunter-gatherer lifestyle does not involve maintaining livestock or having milk products in diet.





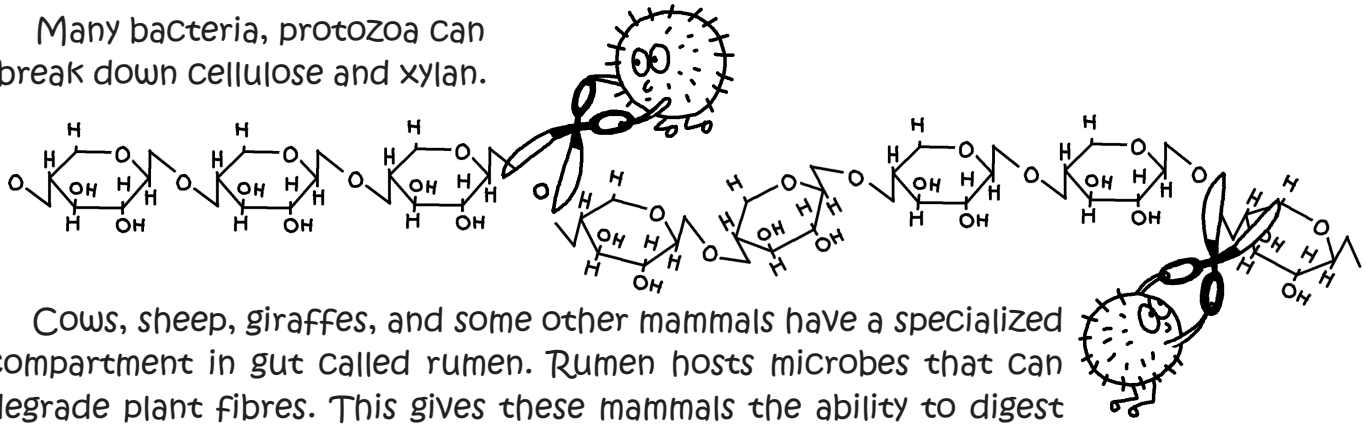
Another interesting thing, Hadza people have the ability to digest plant fibres. They need it because of the presence of tubers in their diet.



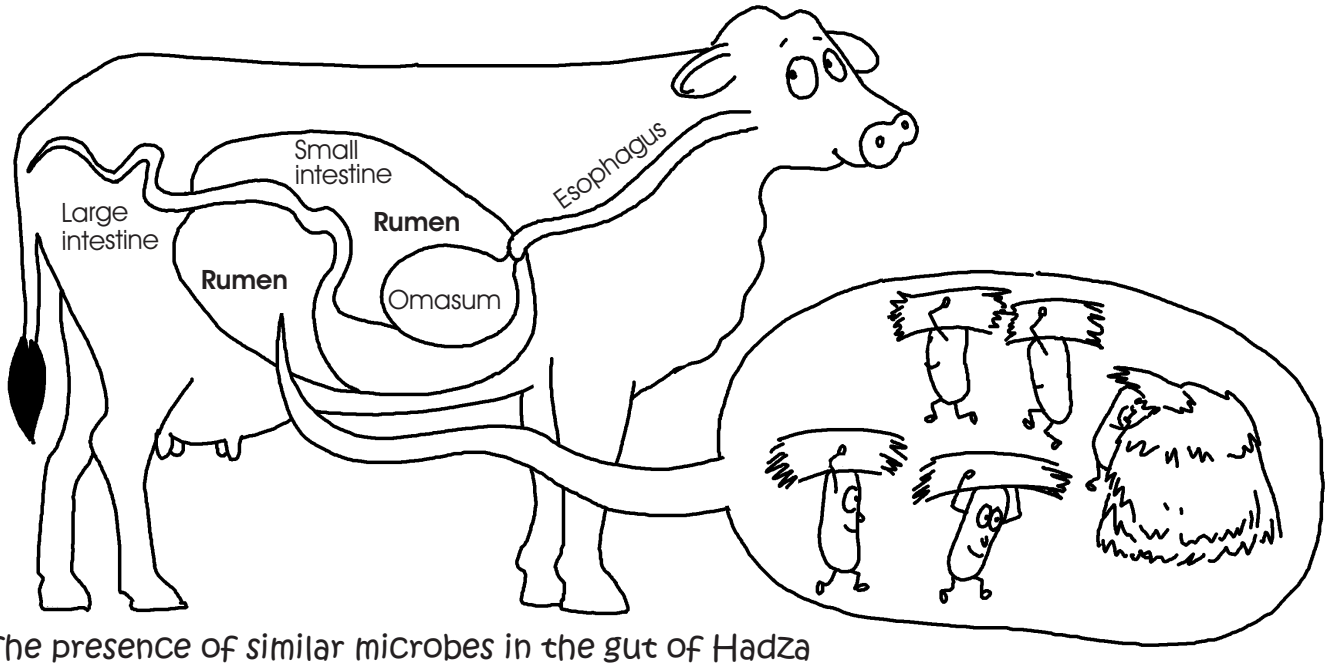
Plant cell walls contain long chain carbohydrates like cellulose and xylan.

Breaking these down is extremely difficult.
Wait, I am just saying that because we can't do it.

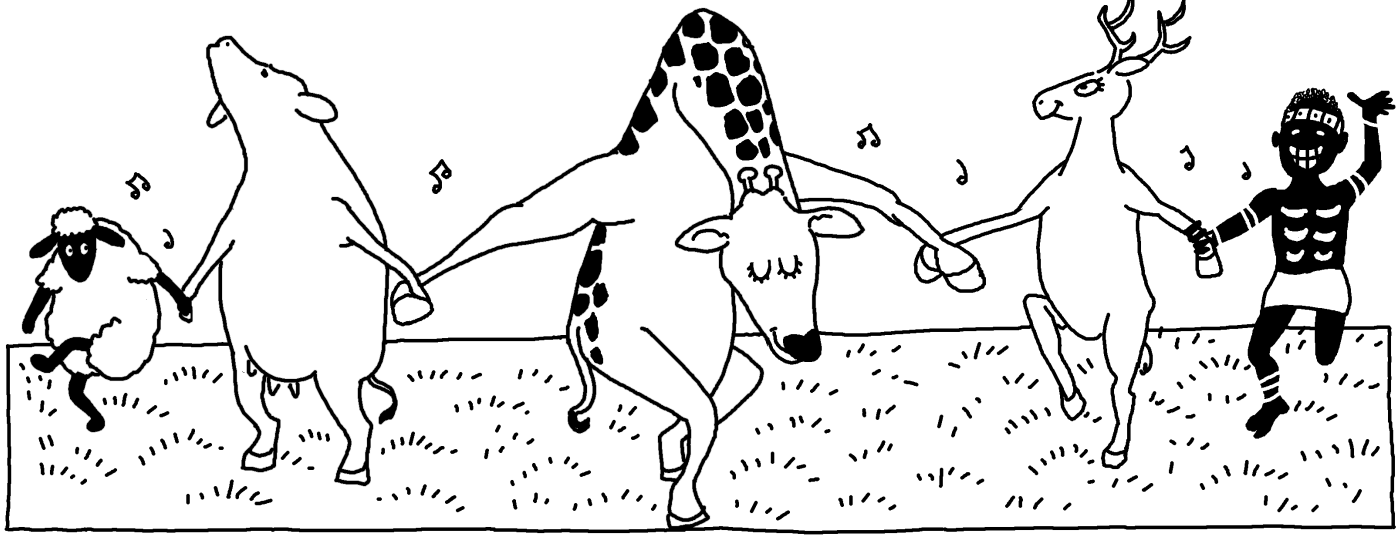
Many bacteria, protozoa can break down cellulose and xylan.



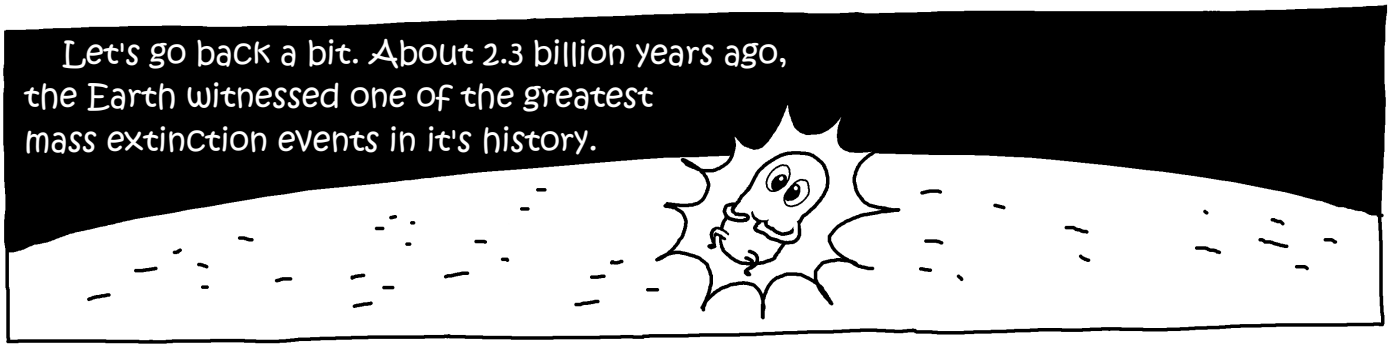
Cows, sheep, giraffes, and some other mammals have a specialized compartment in gut called rumen. Rumen hosts microbes that can degrade plant fibres. This gives these mammals the ability to digest high level of plant fibres in their diet.



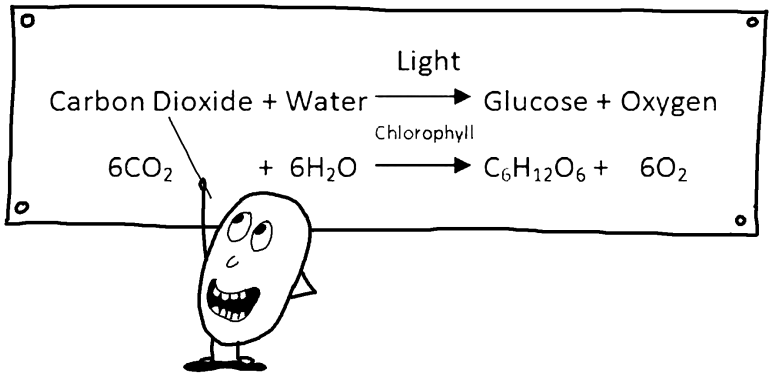
The presence of similar microbes in the gut of Hadza achieves the same goal. It's exciting to think that the guts of Hadza people remember something that ours have forgotten. I am glad we are reminded of it.



Whose body is it anyway?



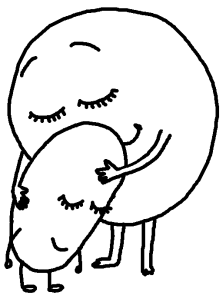
A bacterial phylum called Cyanobacteria had appeared quite recently -- about 200 million years ago.

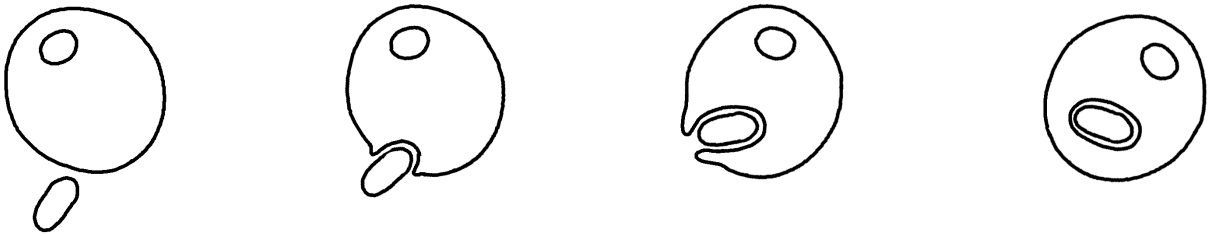


Cyanobacteria obtained their energy from photosynthesis, and created gaseous oxygen as a byproduct. Oxygen was toxic to a huge fraction of organisms present at the time, and these poison breathing bacteria occasioned a mass extinction.

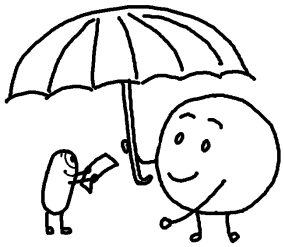
Oxygen is still toxic to life on earth, and aerobic organisms those that can tolerate or require oxygen have elaborate machinery to counter deleterious effects of oxygen. Anaerobic organisms were swept off to live in low oxygen habitats -- deep underwater sediments, certain parts of the digestive tract of animals, etc.

Sometime 1.5 billion years after the Oxygen Catastrophe, a cyanobacterial cell was engulfed by an early eukaryotic cell, and somehow escaped destruction as a foreign entity.





It started inhabiting in the eukaryotic cell, in what's called an endosymbiotic event. Symbiosis is a relationship in which both partners are benefited, and 'endo' refers to one cell living inside another cell.

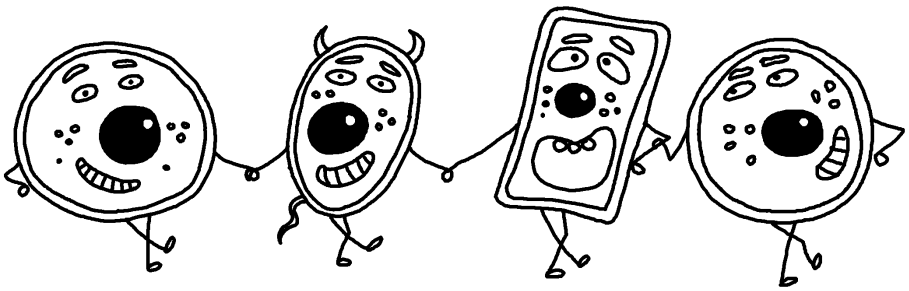


The cyanobacterial cell conferred the ability of photosynthesis to its host cell, and host cell provided shelter.

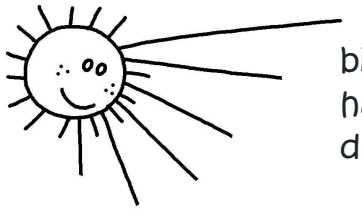
This experiment turned out to be evolutionarily incredibly successful, and the eukaryotic cell gave rise to land plants and red algae among others.

Endosymbiosis has happened multiple times on the Earth. Mitochondria in our cells often called the powerhouse of the cell have resulted from a similar endosymbiotic event.

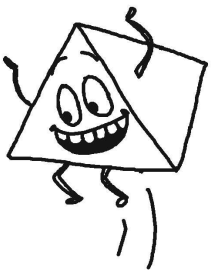
Plants, animals, fungi, all have mitochondria in their cells.



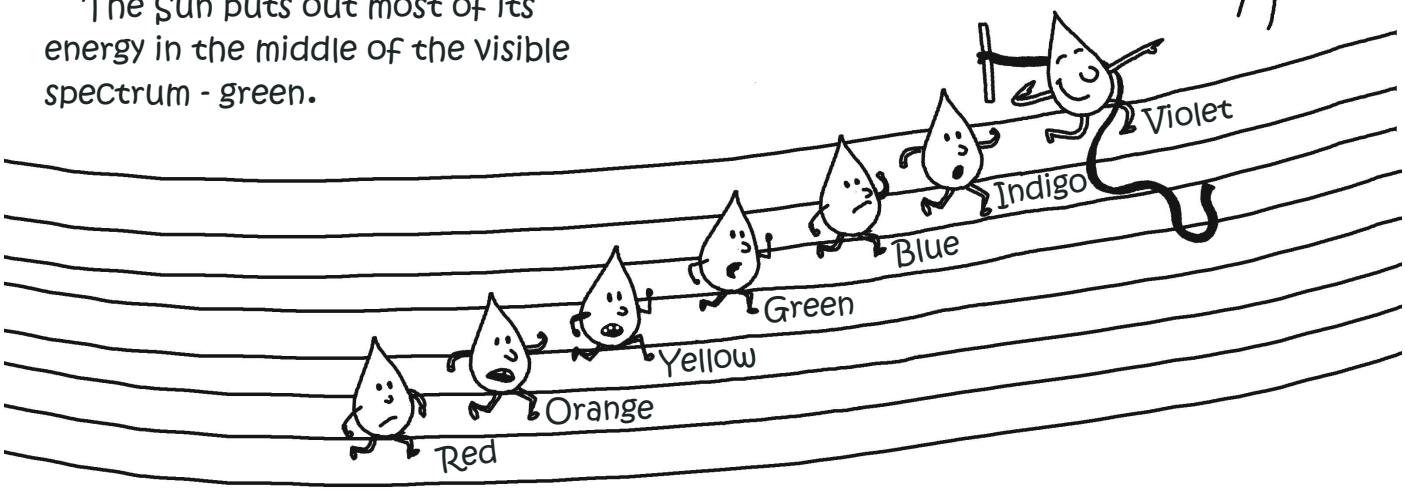
Looks like evolution has converged on the same solution multiple times independently.
This is what evolutionary biologists call a universal feature.



There are other, parochial features ; that are a bit accidental in nature. Did chlorophyll pigment have to be green? Sunlight is made up of many different colours - from red to green to blue.



The Sun puts out most of its energy in the middle of the visible spectrum - green.



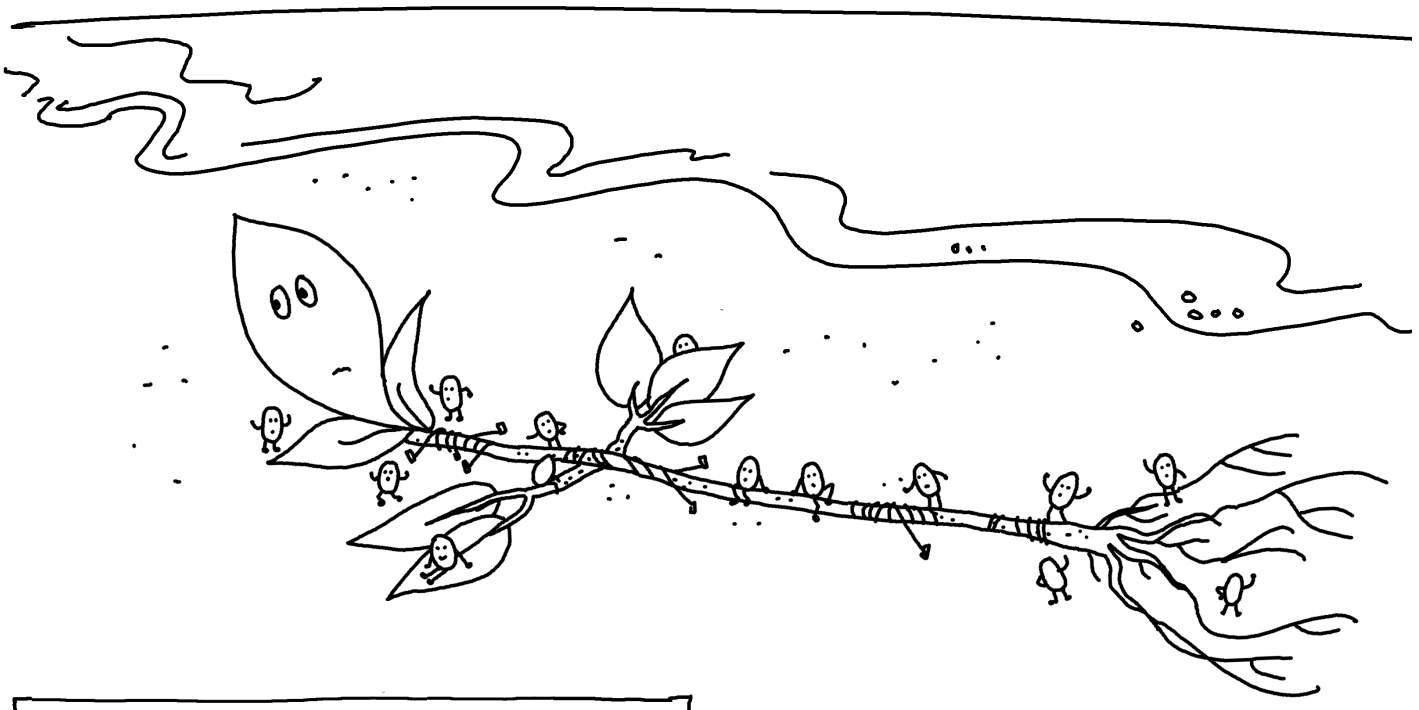
Another point: energy of electromagnetic radiation is inversely proportional to the wavelength. Red light, which is the longest in wavelength, is the lowest in energy.

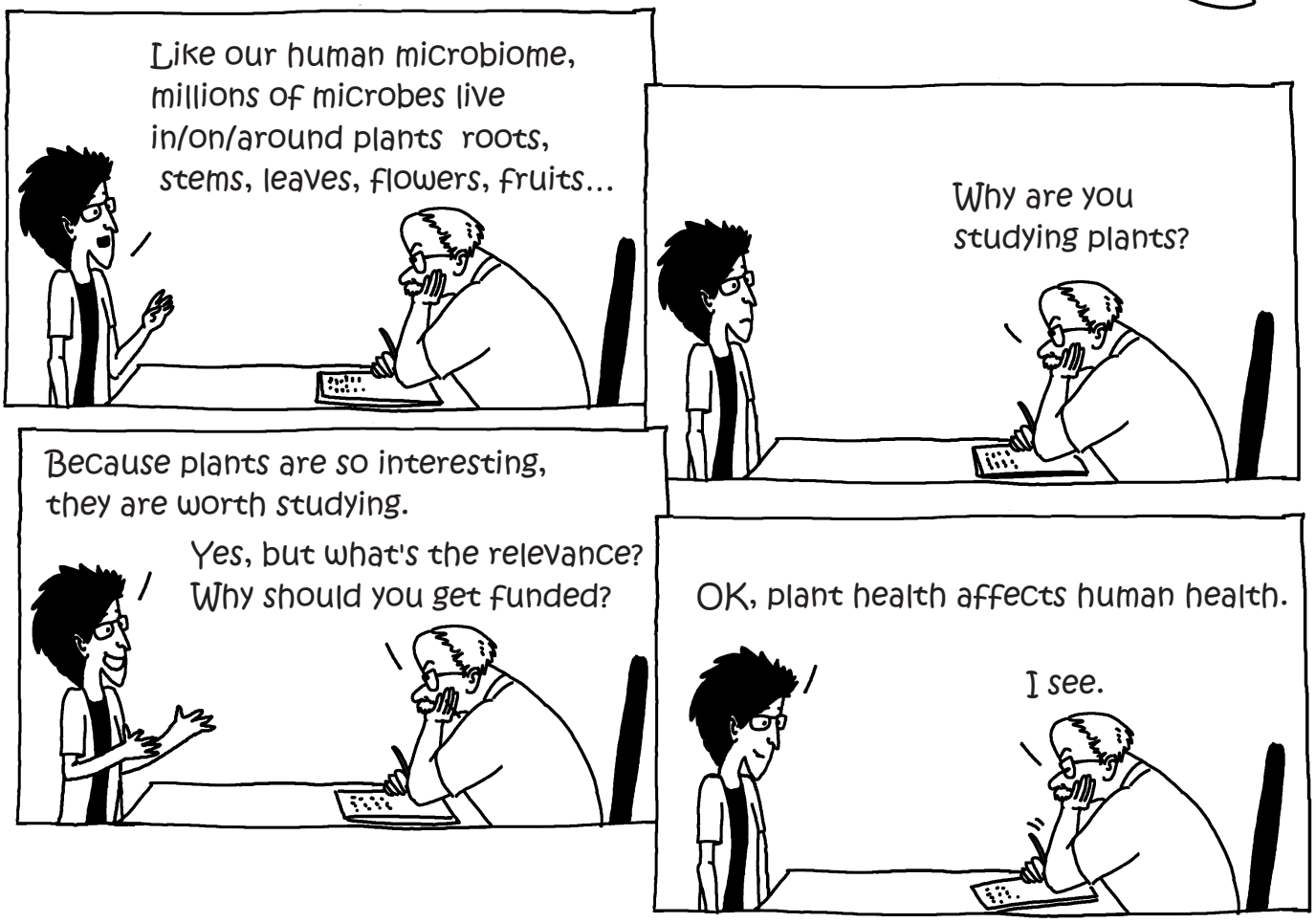
So for a solar-powered leaf to work at maximally, it should absorb most of green light. When you absorb green light, you end up reflecting red and blue light which mix to make purple.

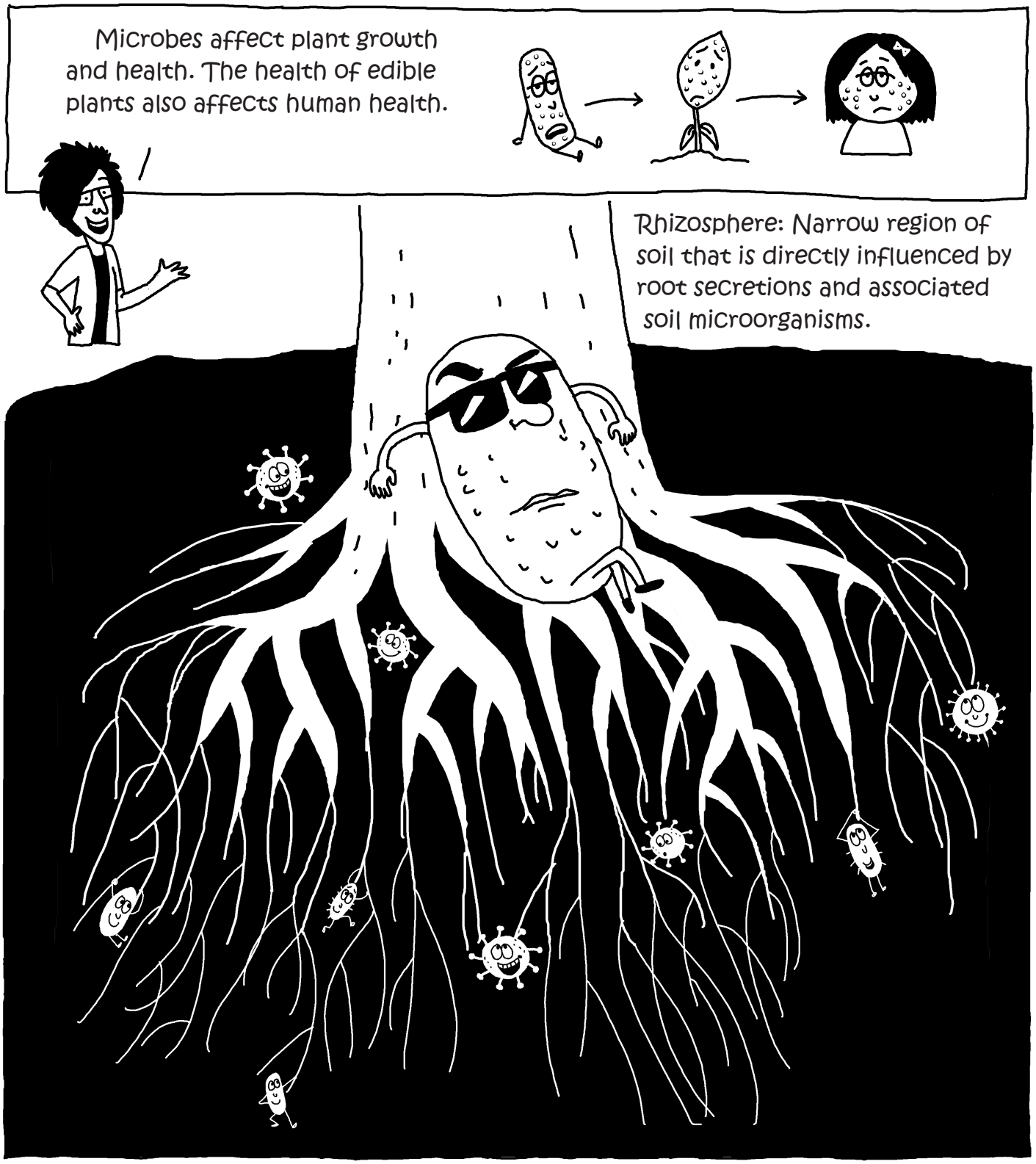
It makes sense for a photosynthesising organism to reflect red light and absorb other wavelengths.

If you give someone a clear drawing--board and tell them to design a photosynthetic organism, they will make it purple or red. But evolution doesn't start with a clear drawing board and it can't see ahead. It just selects whatever works best at the time.

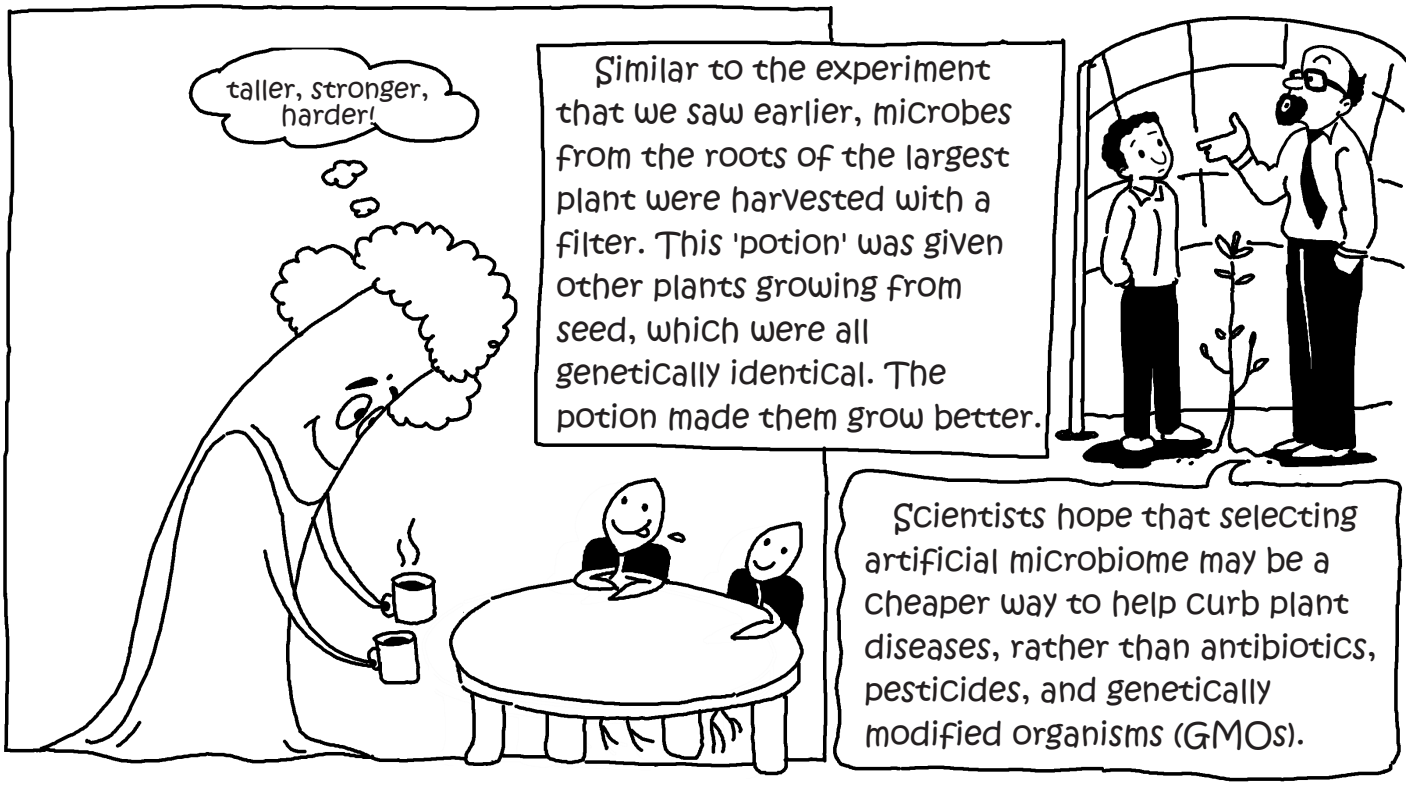
The Elephant's Trunk, and The Tiny People of Lily-put



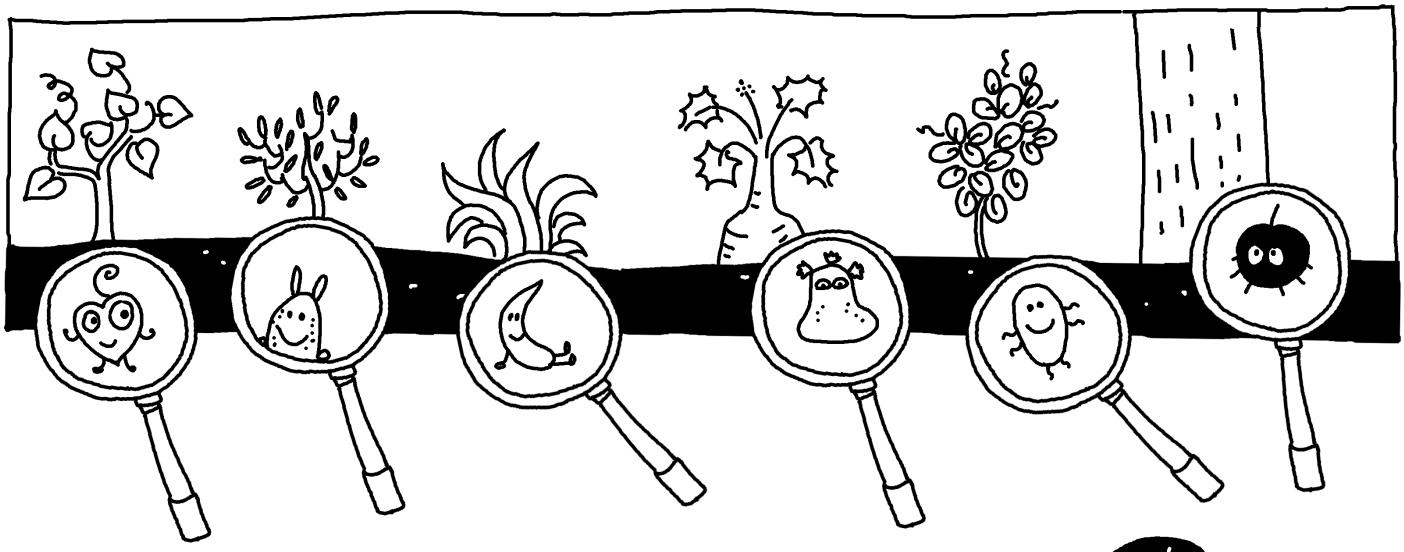




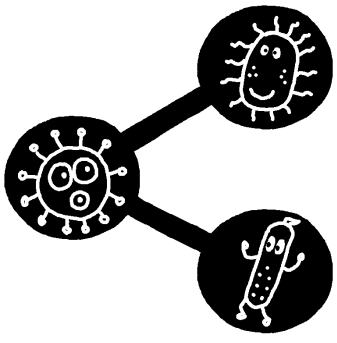
Alison Bennett and colleagues, at the James Hutton Institute,found that the soil microbiome has a strong effect above the ground as well as the way it does below it. Their study has made us realise that microbes living on the roots deserve as much consideration as the roots themselves.



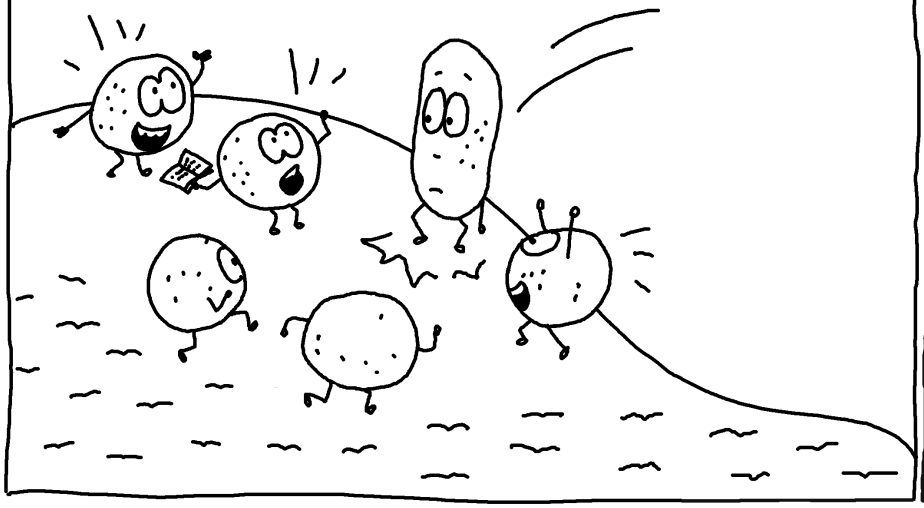
When you grow different plant species on the same soil, the microbial communities that grow around them are also different.



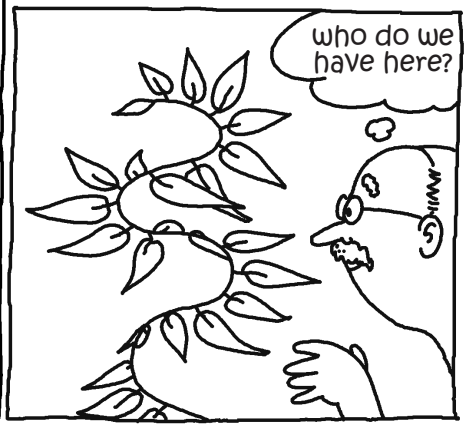
We saw how bacteria have a huge gossip network.

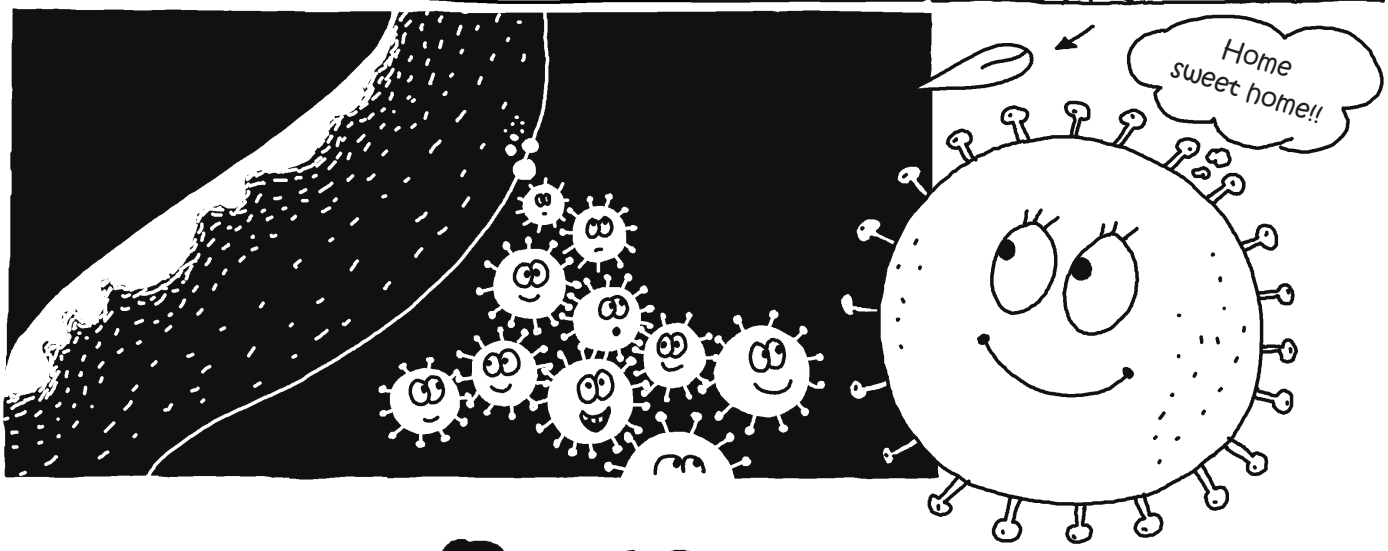


When they land on a plant from somewhere else, the bacteria that are there teach them techniques for survival on plants, and how to acquire nutrients in this new environment.



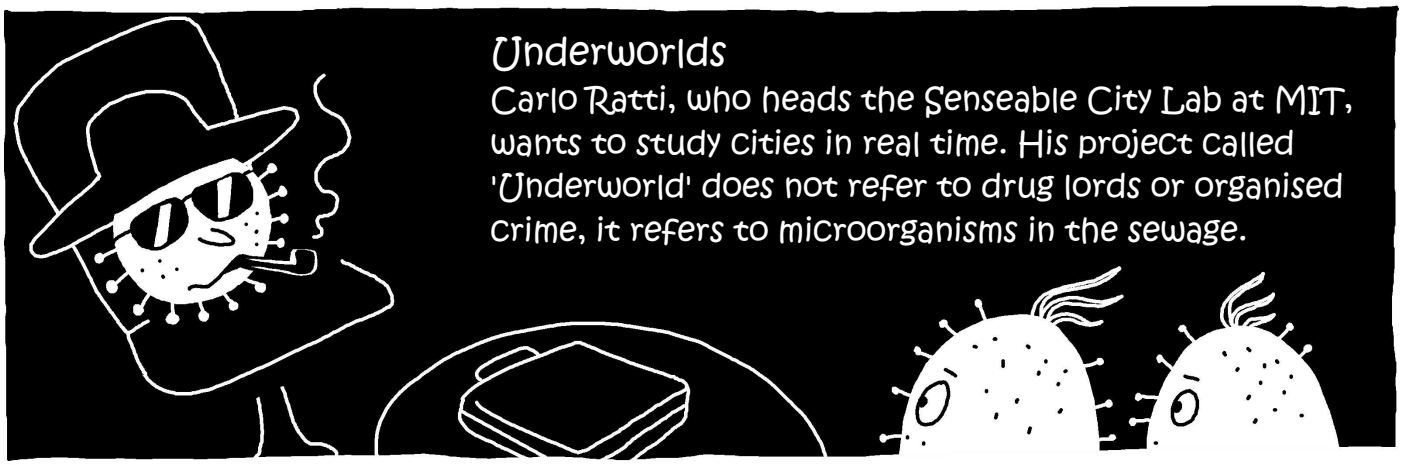
Endophytes are organisms occurring within plant tissues.





Endophytes present in seeds may subsequently colonise the roots and the rhizosphere. Like a child acquires microbial community from its mother, after its birth, so do plants, in a different way.

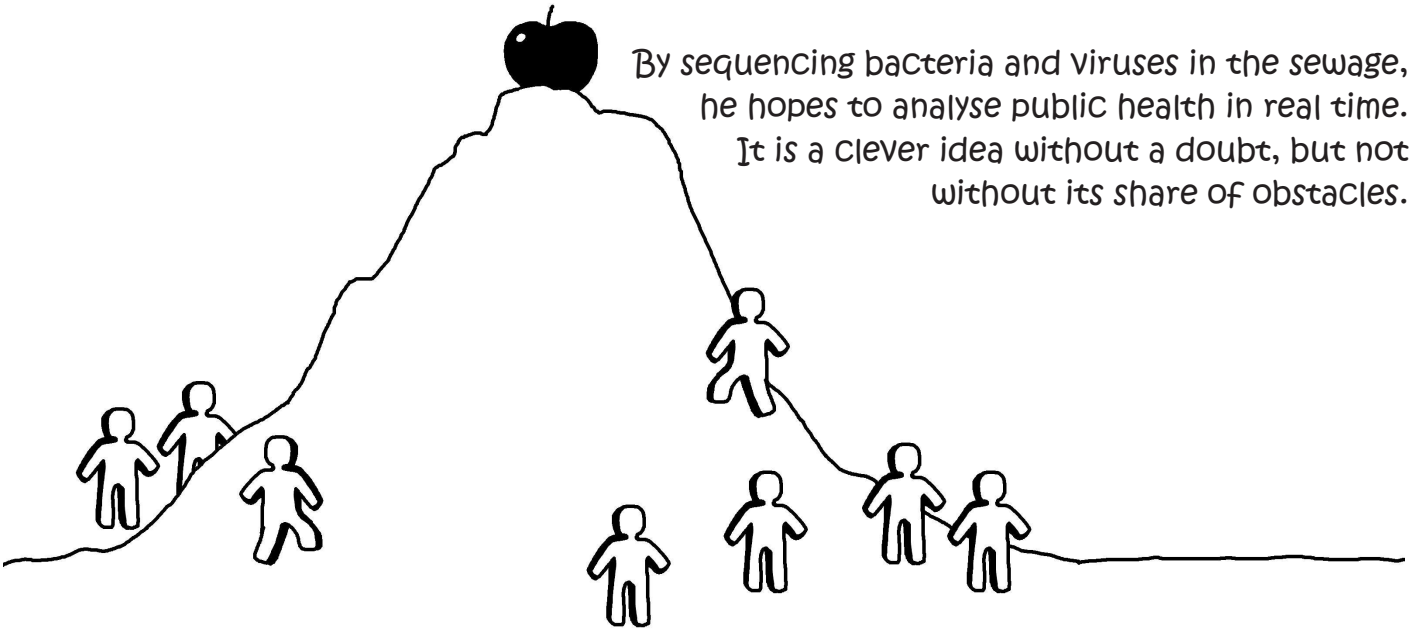
The future (that is already here, in bits and pieces)



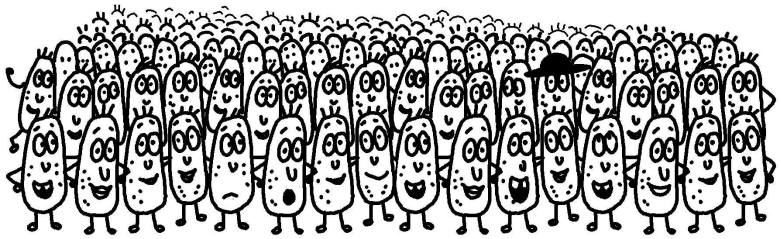
Underworlds

Carlo Ratti, who heads the Senseable City Lab at MIT, wants to study cities in real time. His project called 'Underworld' does not refer to drug lords or organised crime, it refers to microorganisms in the sewage.

By sequencing bacteria and viruses in the sewage, he hopes to analyse public health in real time. It is a clever idea without a doubt, but not without its share of obstacles.

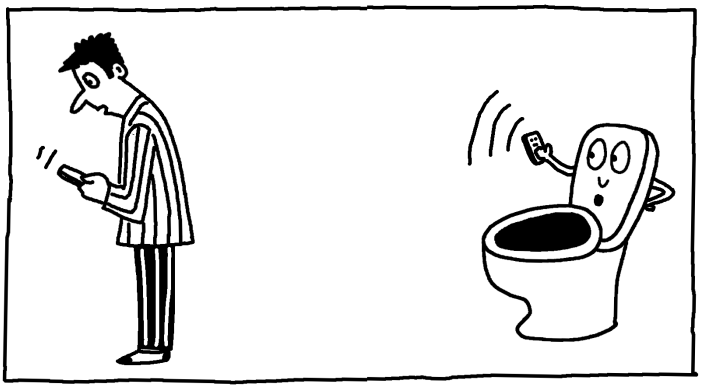


Some microorganisms are more numerous than others, some more resilient than the others, and consequently some pathogens harder to detect than others.

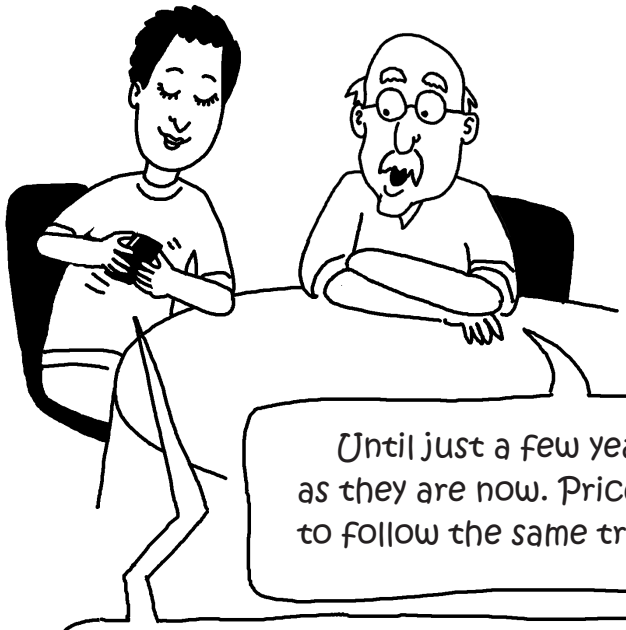


When we surmount these obstacles, though, we will have a new lens to look at public health and epidemiology.

Rob Knight predicted something similar - smart toilets that will sequence the microbes and message you on your smartphone if you need to visit your physician.



Early signs of diseases could be detected, and could lead to prevention of the disease.



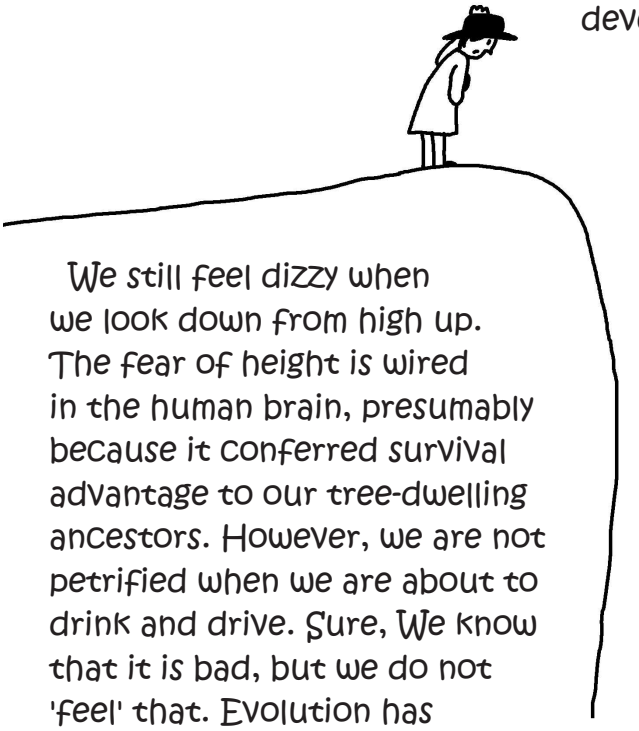
Until just a few years ago, cell phones were not as ubiquitous as they are now. Price and availability of sequencing are likely to follow the same trend.

In developing world, doctors will be able to diagnose the exact cause of nutritional disorders or chronic obstructive pulmonary disorder. They'll be able to prescribe probiotics that will introduce healthier microflora.

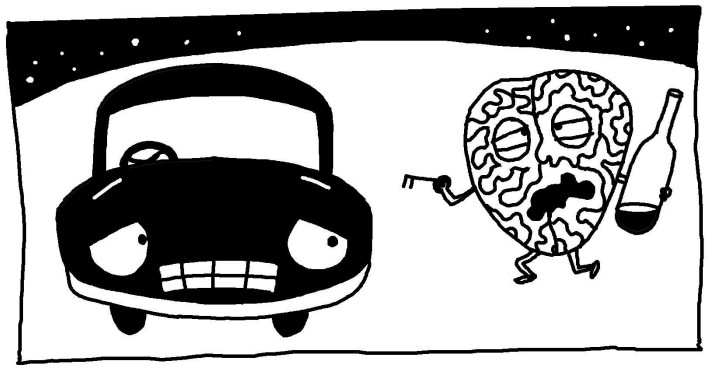
Plus, all of this will likely result in huge increase in our understanding of science.
But of course, you do not tell this to the funding agencies.

Something is in the wind

Prof. Greg Caporaso's lab at Northern Arizona University studies microbes of built environments. When we think about it, we do spend much time indoors. Much more than our ancestors did in Africa about 50,000 years ago. Evolution does not catch up with the speed at which culture develops.

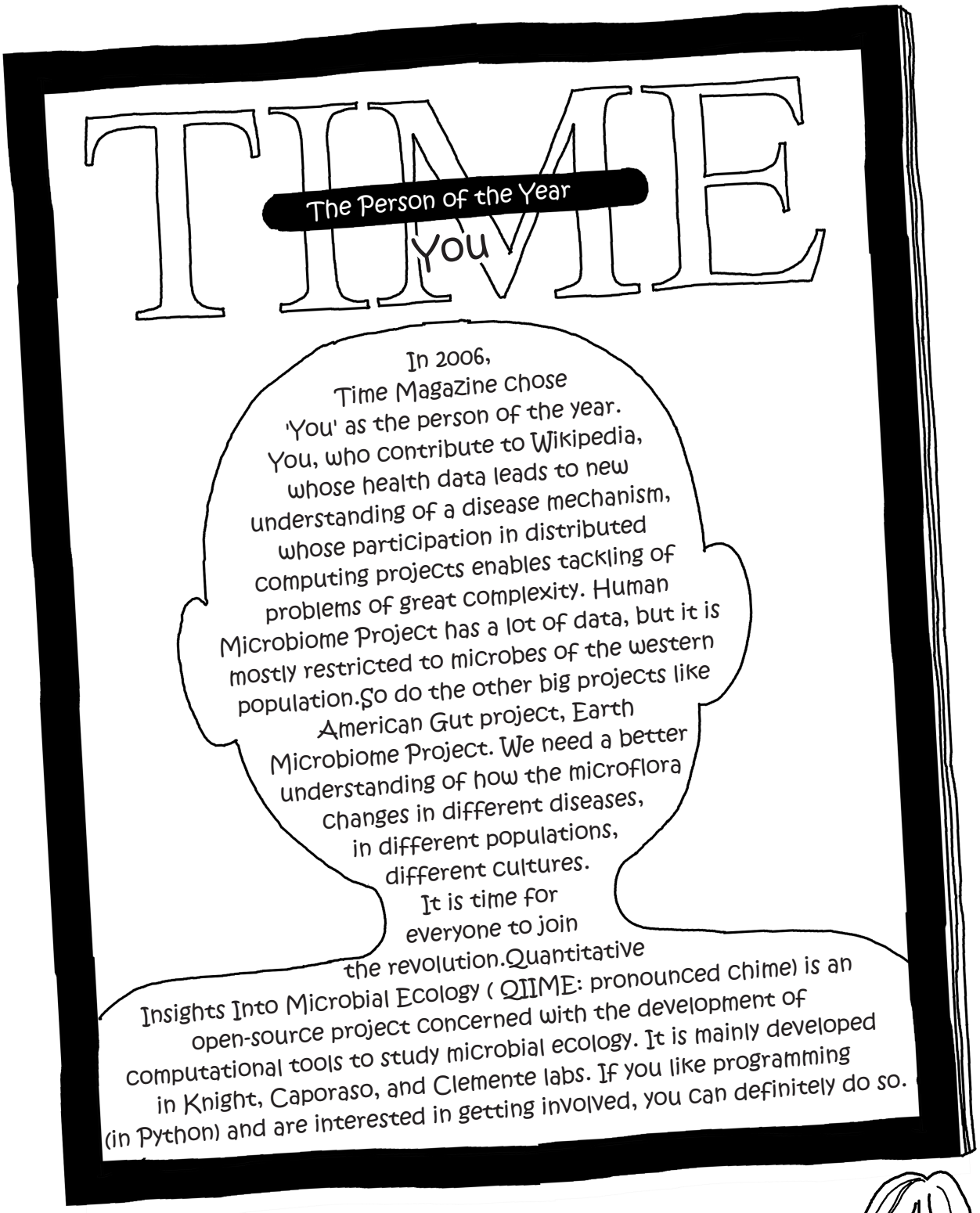


We still feel dizzy when we look down from high up. The fear of height is wired in the human brain, presumably because it conferred survival advantage to our tree-dwelling ancestors. However, we are not petrified when we are about to drink and drive. Sure, We know that it is bad, but we do not 'feel' that. Evolution has not caught up.



Evolution might not have caught up with our habit of living indoors either. Better understanding the microbial landscape might lead to healthier built environments.

Prof. Jose Clemente's and Prof. Jeremiah Faith's labs at Icahn School of Medicine at Mount Sinai focus on studying Inflammatory Bowel Disease(IBD) and food allergies. They also study the effect of diet on gut microbes, and vice versa in germ-free mice models. Evidence has started to accumulate that IBDs like ulcerative colitis respond well to faecal transplant from a healthy person. Looks like microbial ecology might be a key to treating a lot of immune disorders and allergies.



There are an estimated 10^{24} stars in the Universe and 10^{30} bacteria on our planet, and I would argue that the discovery of a microbial species with potentially novel functions would be just as interesting as the discovery of a star. - Prof. Janet Jansson

Notes

Getting in touch with our microbial selves

The incidence of infectious diseases is decreasing, but autoimmune and allergic diseases are on the rise.

Bach, Jean-François. "The effect of infections on susceptibility to autoimmune and allergic diseases." New England journal of medicine 347.12 (2002): 911-920.

Male lions hunt at night.

Loarie, Scott R., Craig J. Tambling, and Gregory P. Asner. "Lion hunting behaviour and vegetation structure in an African savanna." Animal Behaviour 85.5 (2013): 899-906.

The 'Liver'age microbes have

Gut microbes determine the liver toxicity of Tylenol.

Clayton, T. Andrew, et al. "Pharmacometabonomic identification of a significant host-microbiome metabolic interaction affecting human drug metabolism." Proceedings of the National Academy of Sciences 106.34 (2009): 14728-14733.

Gut feelings

Gut microbes help to determine whether you are lean or obese. Smith, Michelle I., et al. "Gut microbiomes of Malawian twin pairs discordant for kwashiorkor." Science 339.6119 (2013): 548-554.

Gut that learns from the food

Transfer of genes encoding CAzymes, from marine bacteria to gut microbes of Japanese people, enable digestion of red algae. Hehemann, Jan-Hendrik, et al. "Transfer of carbohydrate-active enzymes from marine bacteria to Japanese gut microbiota." Nature 464.7290 (2010): 908-912.

Gut microbes can communicate with brain, and alter emotional state of mice.

Bravo, Javier A., et al. "Ingestion of Lactobacillus strain regulates emotional behavior and central GABA receptor expression in a mouse via the vagus nerve." Proceedings of the National Academy of Sciences 108.38 (2011): 16050-16055.

'Us' and 'Them.'

Quorum-sensing system may regulate virulence of microbes in normal flora.

Erickson, David L., et al. "Pseudomonas aeruginosa quorum-sensing systems may control virulence factor expression in the lungs of patients with cystic fibrosis." Infection and immunity 70.42002): 1783-1790.

Gut microbial antigens are presented to developing T cells in thymus.

Cebula A., et al. Thymus-derived regulatory T cells contribute to tolerance to commensal microbiota. Nature (2013) May 9;497(7448):258-62. doi: 10.1038/nature12079.

Hepworth R., et al. Innate lymphoid cells regulate CD4+ T-cell responses to intestinal commensal bacteria. Nature (2013) doi:10.1038/nature12240.

Skin-changers

Families share microbiome with each other. Having a dog results in more sharing of microbes between the members of the families.

Song, Se Jin, et al. "Cohabiting family members share microbiota with one another and with their dogs." Elife 2 (2013): e00458.

Grice, Elizabeth A., et al. "Topographical and temporal diversity of the human skin microbiome." science 324.5931 (2009): 1190-1192.

Infant gut microbes determine risk of SIDS.

Highet, Amanda R., et al. "Gut microbiome in sudden infant death syndrome (SIDS) differs from

that in healthy comparison babies and offers an explanation for the risk factor of prone position." International Journal of Medical Microbiology 304.5 (2014): 735-741.

Where dawn was frozen
Microbiome of Hadza hunter-gatherers is unlike any other human population.
Schnorr, Stephanie L., et al. "Gut microbiome of the Hadza hunter-gatherers." Nature Communications 5 (2014).

Whose body is it anyway?
Mitochondria in our cells often called the powerhouse of the cell have resulted from a similar endosymbiotic event.
Sagan, Lynn. "On the origin of mitosing cells."*Journal of theoretical biology* 14.3 (1967): 225-IN6.

Oxygen was toxic to a huge fraction of organisms present at the time, and these poison breathing bacteria occasioned a mass extinction.
Sperling, Erik A., et al. "Oxygen, ecology, and the Cambrian radiation of animals."*Proceedings of the National Academy of Sciences* 110.33 (2013): 13446-13451.

The Elephant's Trunk, and The Tiny People of Lilliput
Soil microbiome has a strong effect above the ground as well as the way it does below it
Bennett, Alison E., et al. "Plant lignin content altered by soil microbial community."*New Phytologist* 206.1 (2015): 166-174.

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